# VENTILATION AND HEATING

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## PRINCIPLES AND APPLICATION

*A TREATISE*


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CATALOGUE No. 84.



The Smith & Porter Press, Boston.

# INTRODUCTORY

*ALTHOUGH it is scarcely eight years since the first edition of this Treatise was issued, this comparatively brief period has witnessed an almost phenomenal change in public opinion regarding the absolute necessity of good ventilation. That the evil effects of foul air are now generally appreciated is best evidenced by the legal enactments which control the application of ventilating systems in many of our States and municipalities. The growing realization of the necessity of mechanical means to secure positive and reliable results is likewise evident in the extensive and increasing introduction of the Sturtevant System.*

*Appreciating the value of former editions of this Treatise as a means of advancing the cause of improved ventilation and of increasing the application of the Sturtevant System, it is here presented entirely revised and greatly enlarged, with the sincere desire to place before the reader, as clearly and concisely as possible, the points to be considered and the steps to be taken in deciding upon a system of heating and ventilation. The successful operation of the Sturtevant System in thousands of buildings in this country and in Europe is the best evidence we have to offer as to its efficiency.*

*B. F. STURTEVANT CO.*

# VENTILATION AND HEATING

## VENTILATION.

NECESSITY OF VENTILATION. Until quite recently ventilation has been generally regarded as a luxury rather than as an absolute necessity. The discomfort of a poorly-ventilated room has been realized with sufficient vividness, but the difficulty of substituting for the debilitating atmosphere one that is pure and invigorating has in many cases been so far beyond the power of ordinary methods to accomplish that a crowded apartment and a vitiated atmosphere have been looked upon as inseparable. But such an atmosphere is more than uncomfortable and disagreeble; it is positively and undeniably injurious, and continued exposure to it is certain to lead to serious consequences.

The evil effects of lack of ventilation are made only too evident by such facts as that "death-rates have been reduced by the introduction of efficient ventilating systems, in children's hospitals, from 50 to 5 per cent.; in surgical wards of general hospitals, from 44 to 13 per cent.; in army hospitals, from 23 to 6 per cent. * * * Prison records show reduced death-rates, chiefly as the result of effective ventilation, in one case from the yearly average of eighty deaths to one of eight, each period covering the same and a considerable number of years. * * * The annual death-rate among horses in army stables in the German service has been reduced by more roomy quarters and free ventilation from 19 to 1.5, and in a time of epidemic in Boston the number of horses lost in badly-ventilated stables was five to one in those well ventilated."*

While such figures show directly traceable results of breathing impure air, it is not in these most serious consequences alone that its evil effects are revealed. A vitiated atmosphere lowers the vitality, increases the susceptibility to and severity of disease, and decreases the physical and mental working power of the

* Notes on Ventilation and Heating: Prof. S. H. Woodbridge, Mass. Inst. Tech., Boston.

individual, and, while not producing sudden death, nevertheless inevitably shortens life.

AIR. Air being the prime supporter of life, health, and even life itself, are dependent upon the composition of the atmosphere. Although simply a mechanical mixture, yet certain gases of which it is composed exist in almost unalterable proportions in the normal atmosphere. Oxygen and nitrogen, the principal constituents, are present in very nearly the proportion of one part of oxygen to four parts of nitrogen. Carbonic acid gas, the result of all combustion, either slow or rapid, exists in the very small proportion of three to four parts in ten thousand of air, while the aqueous vapor varies greatly with the temperature and exposure to water. In addition there is generally present in air in variable but exceedingly small quantities, ammonia, sulphureted hydrogen, sulphurous acid gas, floating organic and inorganic matter and local impurities.

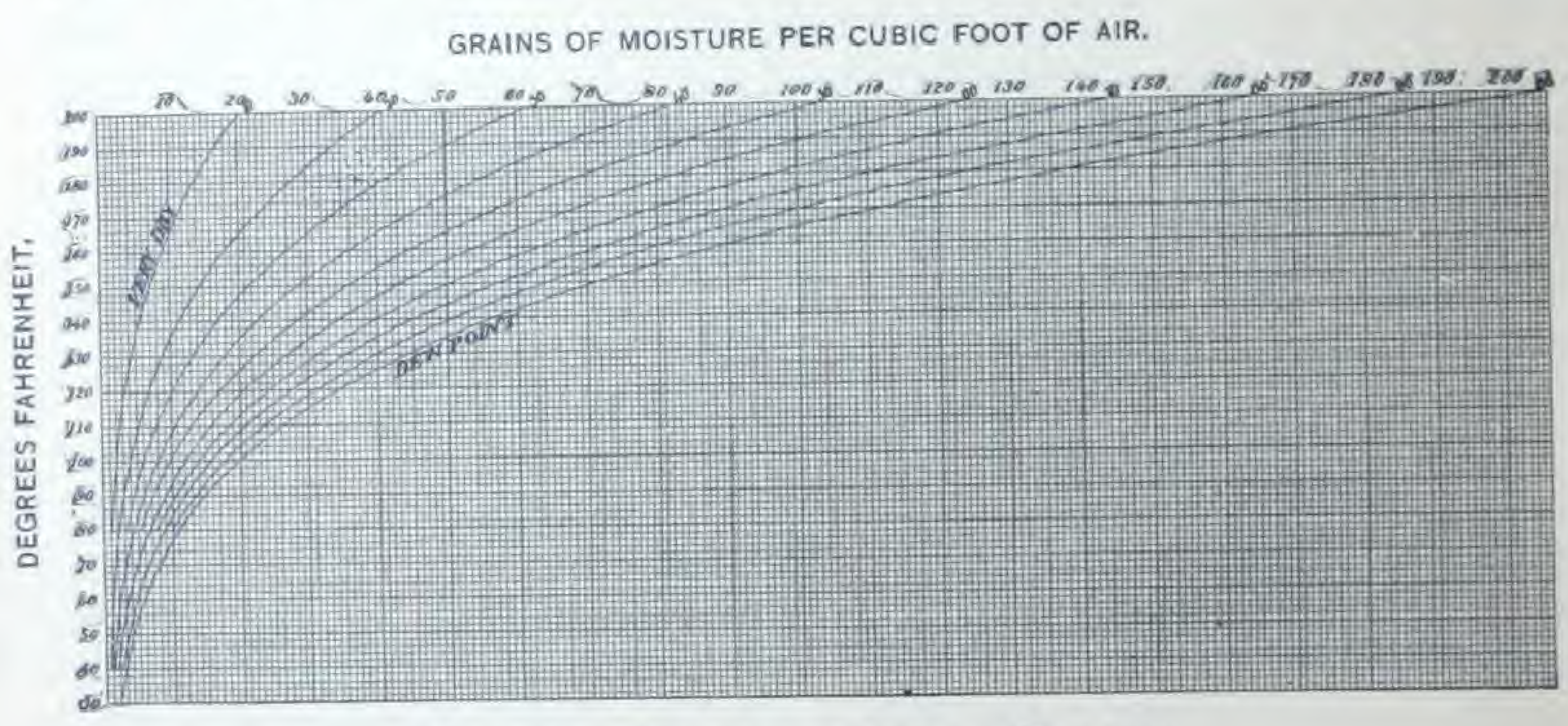



FIG. 1. HYGROMETRIC CHART.

HUMIDITY. The condition of the atmosphere with relation to the amount of vapor or water which it holds in suspension is expressed by the term humidity. Actual Humidity relates to the actual weight of water vapor present in a given unit volume of air, while the term Relative Humidity expresses the relation between the vapor actually present in the air and that which it would contain if saturated. Obviously the air is saturated with moisture when it will hold no more. The actual humidity varies excessively with the temperature; it is, therefore, evident that a statement of the relative humidity gives no indication of the

## TABLE No. 1.

### Of the Weights of Air, Vapor of Water, and Saturated Mixtures of Air and Vapor at Different Temperatures, under the Ordinary Atmospheric Pressure of 29.921 Inches of Mercury.

| Temperature. Fahrenheit. | Volume of Dry Air at different temperatures, the volume at 32° being 1.000. | Weight of a Cubic Foot of Dry Air at different temperatures, in pounds. | Elastic Force of Vapor in inches of Mercury, Regnault. | MIXTURES OF AIR SATURATED WITH VAPOR. Elastic Force of the Air in the Mixture of Air and Vapor in ins. of Mercury. | WEIGHT OF CUBIC FOOT OF THE MIXTURE OF AIR AND VAPOR. Weight of the Air in pounds. | Weight of the Vapor in pounds | Total Weight of Mixture in pounds | Weight of Vapor mixed with 1 pound of Air in pounds. | Weight of Dry Air mixed with 1 lb. of Vapor in pounds. | Cubic Ft. of Vapor from 1 lb. of Water at its own pressure in column 4. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 0° | .935 | .0864 | .044 | 29.877 | .0863 | .000079 | .086379 | .00092 | 1092.4 | |
| 12 | .960 | .0842 | .074 | 29.849 | .0840 | .000130 | .084130 | .00155 | 646.1 | |
| 22 | .980 | .0824 | .118 | 29.803 | .0821 | .000202 | .082302 | .00245 | 406.4 | |
| 32 | 1.000 | .0807 | .181 | 29.740 | .0802 | .000304 | .080504 | .00379 | 263.81 | 3289 |
| 42 | 1.020 | .0791 | .267 | 29.654 | .0784 | .000440 | .078840 | .00561 | 178.18 | 2252 |
| 52 | 1.041 | .0776 | .388 | 29.533 | .0766 | .000627 | .077227 | .00819 | 122.17 | 1595 |
| 62 | 1.061 | .0761 | .556 | 29.365 | .0747 | .000881 | .075581 | .01179 | 84.79 | 1135 |
| 72 | 1.082 | .0747 | .785 | 29.136 | .0727 | .001221 | .073921 | .01680 | 59.54 | 819 |
| 82 | 1.102 | .0733 | 1.092 | 28.829 | .0706 | .001667 | .072267 | .02361 | 42.35 | 600 |
| 92 | 1.122 | .0720 | 1.501 | 28.420 | .0684 | .002250 | .070717 | .03289 | 30.40 | 444 |
| 102 | 1.143 | .0707 | 2.036 | 27.885 | .0659 | .002997 | .068897 | .04547 | 21.98 | 334 |
| 112 | 1.163 | .0694 | 2.731 | 27.190 | .0631 | .003946 | .067046 | .06253 | 15.99 | 253 |
| 122 | 1.184 | .0682 | 3.621 | 26.300 | .0599 | .005142 | .065042 | .08584 | 11.65 | 194 |
| 132 | 1.204 | .0671 | 4.752 | 25.169 | .0564 | .006639 | .063039 | .11771 | 8.49 | 151 |
| 142 | 1.224 | .0660 | 6.165 | 23.756 | .0524 | .008473 | .060873 | .16170 | 6.18 | 118 |
| 152 | 1.245 | .0649 | 7.930 | 21.991 | .0477 | .010716 | .058416 | .22465 | 4.45 | 93.3 |
| 162 | 1.265 | .0638 | 10.099 | 19.822 | .0423 | .013415 | .055715 | .31713 | 3.15 | 74.5 |
| 172 | 1.285 | .0628 | 12.758 | 17.163 | .0360 | .016682 | .052682 | .46338 | 2.16 | 59.2 |
| 182 | 1.306 | .0618 | 15.960 | 13.961 | .0288 | .020536 | .049336 | .71300 | 1.402 | 48.6 |
| 192 | 1.326 | .0609 | 19.828 | 10.093 | .0205 | .025142 | .045642 | 1.22643 | .815 | 39.8 |
| 202 | 1.347 | .0600 | 24.450 | 5.471 | .0109 | .030545 | .041445 | 2.80230 | .357 | 32.7 |
| 212 | 1.367 | .0591 | 29.921 | 0.000 | .0000 | .036820 | .036820 | Infinite. | .000 | 27.1 |

exact amount of vapor present unless the moisture carrying capacity of the air at the given temperature be known.

The accompanying Table No. 1 gives a clear idea of the relations existing between the weights of air and vapor, in saturated mixtures at different temperatures, and will be found exceedingly useful in all calculations relating to heating and drying.

A portion of this table is more clearly represented graphically by the hygrometric chart, Fig. 1, the rapid increase in the capacity of the air for carrying off moisture, as the temperature of the air rises, being indicated by the curved lines, which represent 10, 20, etc., to 100 per cent. humidity: 100 per cent. being the dew point. The horizontal line of figures, from 10 to 200, at the top of the chart, indicates the grains of moisture per cubic foot of air, while the temperature of the air is given in degrees Fahrenheit at the left of the chart.

CARBONIC ACID GAS. This gas is of itself only a neutral constituent of the atmosphere, like nitrogen, and, contrary to general impressions, its unassociated presence in moderately large quantities — as in soda-water manufactories — is neither disagreeable nor particularly harmful. But its presence in the air provided for respiration decreases the readiness with which the carbon of the blood unites with the oxygen of the air to form, in the lungs, further amounts of carbonic acid. It is evident, therefore, that when present in sufficient quantity, it may indirectly bring about not only serious but fatal results. The true evil of a vitiated atmosphere lies in its other constituent gases and in the micro-organisms which are produced in the process of respiration. It is known, however, that these other impurities exist in fixed proportion to the amount of carbonic acid present in an atmosphere vitiated by respiration.

Therefore, as the relative proportion of carbonic acid may be easily determined by experiment, the fixing of a standard limit of the amount in which it may be allowed in ventilated rooms also limits the permissible vitiation of the atmosphere by other impurities.

When carbonic acid is present in excess of 10 parts to 10,000 parts of air, a feeling of weariness and stuffiness, generally accompanied by a headache, will be experienced, while even with 8 parts in 10,000 parts a room would be considered close. For general considerations of ventilation the limit should be placed at 6 to 7 parts in 10,000, thus allowing an increase of 2 to 3 parts per 10,000 over that present in outdoor air, which may be considered to contain 4 parts in 10,000 under the ordinary conditions of a populous district.

The exceedingly bad condition of the air in many halls and theatres is

demonstrated by the following results of experiments by Professor Woodbridge in various buildings in Boston.*

| Place and Time. | | Parts of Carbonic Acid Gas in 10,000 Parts of Air. Floor. | First Balcony. | Second Balcony. | Gallery. |
|---|---|---|---|---|---|
| Boston Theatre. | 1st Test, | — | — | — | 48.7 |
| | 2d Test | 39.13 | 42.86 | 44.72 | 48.14 |
| | 3d Test, | — | 35.48 | — | 45.12 |
| Globe Theatre. | Three-fourths full, | 23.38 | 35.88 | 34.59 | — |
| | One-half full | 19. | 24.16 | 24.72 | — |
| Huntington Hall.—Ventilating apparatus unused | | | | | 18.48 to 17.24 |
| Young Men's Christian Association | | | | | 36.43 to 32.59 |
| Trinity Church.—Gallery | | | | | 20.52 to 19.12 |

In these cases injurious effects could not fail to ensue from a continued exposure to such seriously contaminated air.

AMOUNT OF AIR REQUIRED FOR VENTILATION. Under the general conditions of outdoor air, namely 70° temperature and 70 per cent. of complete saturation, an average adult man, when sitting at rest as in an audience, makes 16 respirations per minute of 30 cubic inches each, or 480 cubic inches per minute. Under the previously assumed conditions of 70° temperature and 70 per cent. humidity, the air thus inhaled will consist of about $\frac{1}{5}$ oxygen and $\frac{4}{5}$ nitrogen, together with about $1\frac{7}{10}$ per cent. aqueous vapor and $\frac{4}{100}$ of a per cent. carbonic acid. By the process of respiration the air will, when exhaled, be found to have lost about $\frac{1}{5}$ of its oxygen by the formation of carbonic acid, which will have increased about one hundred-fold, thus forming about 4 per cent., while the water vapor will form about 5 per cent. of the volume. In addition, the inhaled air will have been warmed from 70° to 90°, and, notwithstanding the increased proportion of carbonic acid,— which is about one and one-half times heavier than air,— will, owing to the increase of temperature and the levity of the water vapor, be about 3 per cent. lighter than when inhaled. Thus it will be seen that this vitiated air will not fall to the ground, as has often been presumed, but will naturally rise above the level of the breathing line, and the carbonic acid will immediately diffuse itself into the surrounding air. In addition to the carbonic acid exhaled in the process of respiration, a small amount is given off by the skin. Furthermore, $1\frac{1}{2}$ to $2\frac{1}{2}$ lbs. of water are evaporated daily from the surface of the skin of a person in still life. If the air supply at 70° is assumed to have a humidity of 70 per cent. and to be saturated when it leaves the body at a higher temperature, then at least 4 cubic feet of air per minute will be required to carry away this vapor.

*Technology Quarterly, Vol. II, No. 2.

Taking into consideration these various factors, it becomes evident that at least $4\frac{1}{2}$ cubic feet of fresh air will be required per minute for respiration and for the absorption of moisture and dilution of carbonic acid gas from the skin. This, however, is only on the assumption that any given quantity of air having fulfilled its office, is immediately removed without contamination of the surrounding atmosphere; but this condition is impossible, for the spent air from the lungs, containing about 400 parts of carbonic acid gas in 10,000, is immediately diffused in the atmosphere. The carbonic acid does not fall to the floor as a separate gas, but is intimately mixed with the air and equally distributed throughout the apartment.

It must then be evident that ventilation is in effect but a process of dilution and that when the vitiation of the air discharged from the lungs is known and the degree of vitiation to be maintained in the apartments is decided, the necessary constant supply of fresh air to maintain this standard may be very easily determined. For the purpose of calculation, 0.6 cubic feet per hour is accepted as the average production of carbonic acid by an adult at rest and the proportion of this gas in the external air as 4 parts in 10,000. If, therefore, the degree of vitiation of the occupied room be maintained at, say, 6 parts in 10,000, there will be permissible an increment of only 2 parts in 10,000 above that of the normal atmosphere, or 2-10,000=.0002 of a cubic foot of carbonic acid in each cubic foot of air. The 0.6 cubic foot of carbonic acid produced per hour by a single individual will, therefore, require for its dilution to this degree 0.6÷.0002=3,000 cubic feet of air per hour. Upon this basis the following Table has been calculated:

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cubic Feet of Air Containing 4 Parts of Carbonic Acid in 10,000 Supplied per Person. | Per Hour. | 6000 | 4000 | 3000 | 2400 | 2000 | 1800 | 1714 | 1500 | 1200 | 1000 | 525 | 375 | 231 |
| | Per Min. | 100 | 66.6 | 50 | 40 | 33.3 | 30 | 28.6 | 25 | 20 | 16.6 | 9.1 | 6.2 | 3.8 |
| Degree of Vitiation of the Air in the Room. | Parts of Carbonic Acid in 10,000. | 5 | 5.5 | 6 | 6.5 | 7 | 7.33 | 7.5 | 8 | 9 | 10 | 15 | 20 | 30 |

The figures indicate absolute relations under the stated conditions, and are generally applicable to the ventilation of schools, churches, halls of audience and the like, where the occupants are reasonably healthy and remain at rest. But the absolute air volume to be supplied cannot be specified with certainty in advance, without a thorough knowledge of all the conditions and modifying circum-

stances,— in fact, the climate, the construction of the building, the size of the rooms, the number of occupants, their healthfulness and their activity, together with the time during which the rooms are occupied, all have their direct influences. Under all these considerations, it is readily seen that no standard allowance can be made to suit all circumstances, and results will be satisfactory only in so far as the designer understandingly, with the knowledge of the various requirements as they have here been given, makes such allowance. The following schedule of air supply, in cubic feet per hour, as proposed by Dr. Billings* is here presented as showing relatively the volumes recommended by him in different classes of buildings:

| | Cubic Feet per Hour. |
|---|---|
| Hospitals, | 3,600 per Bed |
| Legislative Assembly Halls, | 3,600 per Seat |
| Barracks, Bedrooms and Workshops, | 3,000 per Person |
| Schools and Churches, | 2,400 per Person |
| Theatres and Ordinary Halls of Audience, | 2,000 per Seat |
| Office Rooms, | 1,800 per Person |
| Dining Rooms, | 1,800 per Person |

These figures are for buildings in which there is no special contamination of the atmosphere beyond that which their use would indicate. Where smoke, dust, noxious gases or infectious germs are produced, and above all where the illumination is furnished by candles, lamps or gas, additional provision of air supply must be made. Thus a single 4 1-2 gas burner demands 45 cubic feet of air per minute and the resulting carbonic acid gas, unless sufficiently diluted, or immediately removed, will seriously vitiate the air. The introduction of modern methods of incandescent electric lighting has done much to simplify and facilitate the solution of problems in heating and ventilation.

The air volumes recommended for ventilation by various investigators of the past century show a constant increase in their quantity as the years progress. As good ventilation is only a relative term, depending largely on one's experience and the possibility of improvement, it must be evident that perfect ventilation in the broadest sense can only be secured in the open air. It is, therefore, the province of ventilation to approach as near this perfection as means and expediency will permit.

The crystallization of public opinion into statute laws, looking to adequate methods of ventilation for school, theatre, church and factory, has resulted in the establishment of a basis or limit which will meet the approval of those upon whom is placed the responsibility of enforcing these laws. Under the law as first

* Ventilation and Heating: John S. Billings, New York, 1893.

passed in Massachusetts, the attempt was made to secure 50 cubic feet per head per minute, but it was soon discovered that such provision would necessitate the remodelling of practically every building in the State. Therefore, financial outweighed all other influences, and the limit was dropped to 30 cubic feet, a figure adopted not because of hygienic deductions but because it appeared upon investigation to be the practical limit attained by existing methods in the commonwealth.

This basis of 30 cubic feet has been very generally adopted throughout the country, and is to-day recognized as the minimum volume to be provided in any system of ventilation worthy of the name. As the benefits of good ventilation are still further recognized, and the ability of the fan to provide practically unlimited volumes of air is better appreciated, this limit will gradually rise until we may one day witness the compulsory provision of air for the purpose of ventilation in such volumes as to render further improvement of no practical benefit.

# VENTILATION AND HEATING

## HEATING.

HEAT OF HUMAN BODY. The normal internal temperature of the human body is very near 100°, independent of the temperature of the surrounding air. By respiration the continuous process of slow combustion is kept up,—the oxygen of the air, uniting with the carbon of the blood passing through the lungs, to form carbonic acid. As in any case of combustion, overheating takes place unless provision is made for the distribution of the heat generated, so the body is kept at its normal temperature only by the abstraction of heat from it. The actual *heating* of the body is not the ultimate object of heating; but, in reality, provision is made for the abstraction of heat generated by the vital functions without making too great a demand upon the physical endurance ot the individual.

MEANS OF DISPERSION OF HEAT. Three means are provided for the healthful dispersion of heat from the human body. First. By radiation to the air and surrounding objects. Second. By conduction, principally to the air immediately in contact with the body. Third. By evaporation of moisture from the lungs, throat and skin. Under the conditions of summer air, the last two are generally about equal, but the greater part of the heat is dissipated by the first means. Air is a nearly perfect non-conductor of heat, but radiation takes place through it readily. We may enter a room having a temperature of 75°, with walls at 50°, and feel chilled, simply because heat is rapidly radiated from the body through the air to the colder walls. In comparatively dry air equality of temperature is kept up by a steady but imperceptible evaporation from the skin. In moist air this rapid evaporation is prevented and the water is deposited as perspiration, the air being too heavily laden to take it up. On the other hand, when the air is in motion it increases both evaporation and conduction by the constant bringing of fresh air to take the place of that already moistened or heated. If, under any circumstances, one of these three means fails to abstract heat rapidly enough, the removal by the other means is increased, and equilibrium of temperature kept up.

# VENTILATION AND HEATING

FORCED CIRCULATION. In the system of forced circulation by means of that universally-adopted machine,—a fan or blower,—the action is *absolute* and *positive*. The whole matter cannot be better expressed than in the words of the late Robert Briggs,* a man of large experience in practical ventilation and heating: "It will not be attempted at this time to argue fully the advantages of the method of supplying air for ventilation by impulse through mechanical means,—the superiority of forced ventilation, as it is called. This mooted question will be found to have been discussed, argued and combated on all sides, in numerous publications, but the conclusion of all is, that if air is wanted in any particular place, at any particular time, it must be put there, not allowed to go. Other methods will give results at certain times or seasons, or under certain conditions. One method will work perfectly with certain differences of internal and external temperatures, while another method succeeds only when other differences exist. One method reaches to relative success whenever a wind can render a cowl efficient. Another method remains perfect as a system if no malicious person opens a door or window. No other method than that of impelling air by direct means, with a fan, is equally independent of accidental natural conditions, equally efficient for a desired result, or equally controllable to suit the demands of those who are ventilated."

EFFICIENCY OF THE FAN. Further on in the same paper, Mr. Briggs states that:—"In all mechanical appliances, that is simplest which most positively and directly effects the purpose in view; and in this matter of supplying air, it may be claimed that the process of impelling it, when and where wanted, is at once the most certain and efficient, and that the fan (in its form of a rotating wheel with vanes for large uses), is the simplest and readiest machine for impelling air. It will not be attempted at this time to discuss the theory of Rotary Fans. The fan itself will simply be accepted as one of the recognized appliances in the construction of ventilating apparatuses, available with other mechanisms in established forms and defined types for American practice."

After showing the enormous expense of moving air by allowing it to pass over steam-heated surfaces (thus creating a difference in pressure due to a difference in temperature) compared with the expense of moving equal quantities of air by means of a fan, Prof. S. H. Woodbridge,† of the Massachusetts Institute of Technology, states that "among the many mechanical devices for the movement of air through channels, none are so economical of power and convenient in use as the fan."

* On the Ventilation of Halls of Audience: Robert Briggs; Proc. Am. Soc. Civil Engineers, May, 1881.
† Notes on Ventilation and Heating: Prof. S. H. Woodbridge, Mass. Inst. Tech., Boston.

A practical illustration will best serve to prove the force of this statement. A vent flue, one square foot in cross sectional area and 40 feet high, is arranged to withdraw air from a room having a temperature of 70° while the outdoor air is at 20°; the flue being provided with an accelerating coil, which heats the air within to 90°. By the ordinary methods of calculation, it may be shown that the theoretical velocity of the air thus produced in the flue will be 1,149.4 feet per minute, and that there will be expended for its movement 394.6 heat units. A fan, on the other hand, would theoretically require, to produce the same air movement, only .703 units of heat. But these figures are purely theoretical, and the efficiency of the two methods must enter to give the true relation.

Assuming for the flue an average efficiency of 60 per cent., there will actually be required for this method 657.7 units of heat. On the other hand, making the fair assumptions that of the heat units in the fuel 70 per cent. is delivered in the form of steam, that this steam is utilized in an engine having an efficiency of only 10 per cent., while the fan driven thereby turns into useful work only 25 per cent. of the power delivered to it by the engine, the combined efficiency of the system will be reduced to 1.75 per cent., calling for a heat expenditure of 40.17 units. Even under this practical condition, it appears that the movement of air by aspiration still requires 16.37 times as much heat (which is simply a measure of the coal bill), as a fan producing the same results. Of course, a change in the conditions will affect this relation to a reasonable extent, but it is certainly evident that the thermal or aspiration system requires more fuel than the fan under all practical conditions as they exist in any system of heating and ventilation.

METHODS OF HEATING. In the progress of civilization more efficient arrangements for heating have gradually been adopted. Fireplaces, stoves and furnaces have, in the order named, been introduced as means of warming. For small rooms, as in dwellings, they answer very well; but the effect of opening or closing windows and doors and of changes in the atmospheric conditions is too well appreciated to need recital here. It will certainly be admitted that a building can seldom be found where the heated air is *properly* and *satisfactorily* furnished and distributed by a furnace; some of these influences are sure to act, and at times it will be impossible to heat certain rooms without the closing of doors or shutting of registers in other rooms.

More refined are the methods of heating which are dependent upon the use of steam or hot water, confined in radiators or coils. Under systems of direct radiation, these are placed in the rooms to be heated, but seldom with any

provision for the introduction of fresh air. By the indirect method of placing the heating surface in ducts connecting with the rooms and permitting outdoor air to pass across such surfaces, a much nearer approach is made to good ventilation. But still it is practically impossible by such means alone to produce the air-flow and maintain the temperature necessary for a large and crowded apartment. It is evident that some positive means, like the fan, must be applied to render such systems reliable at all times.

VENTILATION AND HEATING COMBINED. Experience has clearly demonstrated that in this climate no system of ventilation can be successfully operated by itself and independently of the method of heating that may be adopted. It is, in fact, a vital element of success that the two systems be most intimately combined, for they are clearly interdependent, and when properly applied are so interwoven in their operation and results that disunion is certain to bring about failure. For the purpose of ventilation, the fan was first applied upon a practical scale about the middle of this century, but only to a limited extent, and it was not until the fan and the steam heater in marketable form were introduced by B. F. Sturtevant that the so-called "Blower System" became a reality. The System, of which these two elements are the most important factors, as originally installed by this house, has naturally been known as "The Sturtevant System." This System is at once practical, successful and economical; for, air being the natural conveyor of heat, it may, when properly warmed and supplied, perform the double office of heating and ventilating. As applied, the Sturtevant System forces the air into the apartment by the pressure or *plenum method*. When a fan is arranged to exhaust or withdraw the air from an enclosed space, the term vacuum, or *exhaust method*, is almost universally applied.

THE EXHAUST METHOD. There are many objections to the adoption of the exhaust method in this country, and, as a rule, it should be avoided. When exhausting, a partial vacuum is created within the apartment, and all currents and leaks are inward; there is nothing to govern definitely the quality and place of introduction of the air, and it is difficult to provide proper means for warming it. Under this system provision is often made for drawing the air across steam pipes placed opposite windows, with the expectation that the air will become thoroughly heated in passing across them. Such oftens fails to be the case, for the most direct course is taken by the air toward the existing vacuity, and only a portion of the heating surface is utilized.

THE PLENUM METHOD. On the other hand, when the air is forced in, its quality, temperature and point of admission are completely under control; in a word, the method is *positive;* all spaces are filled with air under a slight pressure, and the leakage is outward, preventing the drawing of polluted air into the room from any source. But, above all, ample opportunity is given for properly tempering the air by means of heaters, either in direct communication with the fan itself or in separate passages leading to the various rooms.

DETERMINATION OF HEATING CAPACITY REQUIRED. The amount of heat required to comfortably warm a given space is dependent upon many variables. Most important of all is the difference in temperature between the indoor and the outdoor air; for the rate of passage of heat through walls is practically in direct proportion to the difference in temperature upon the opposite sides of the wall. The material of such walls, of course, governs the rapidity of this loss; — under general conditions, wooden buildings most rapidly dissipate the heat, and stone next, while brick buildings best retain the heat. Obviously the relative area of window surface materially affects the loss of heat, while the amount of wall and window surface, in proportion to the cubic contents of the apartment; the climate, the location (whether high or low, or upon the side of the building subject to the most chilling winds), and the method of heating,— all have an influence. With so many modifying considerations, it is evident that no unalterable rule can be given for heating all classes of buildings, but that satisfactory results can only be obtained by separate calculation for each.

From the known heat-transmitting power of various forms of construction, the loss of heat may be determined with reasonable accuracy. The conductivity of such surfaces is generally expressed in the number units of heat transmitted per hour per square foot of surface for each degree difference between the temperatures of its two sides. The entire subject has been very carefully investigated by the German Government, and the results incorporated in a series of coefficients — representing the best practice — to be employed in determining the relative rates of transmission for various substances employed in construction. It is prescribed by law that these coefficients shall be applied in the design of its public buildings, and generally used in Germany for all buildings.

These values have been transformed into American units by Alfred R. Wolff, M. E.,* and by him slightly modified to suit our climatic conditions. The most important of these coefficients — representing the heat transmission in units per hour per square foot of surface per degree difference in temperature — are here presented:

*The Heating of Large Buildings: Alfred R. Wolff, M.E., New York.

THE COEFFICIENT BEING FOR EACH SQUARE FOOT OF BRICK WALL, OF THICKNESS:

| Thickness of Brick Wall, in Inches, | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| Coefficient . . . . . . . . | .658 | .458 | .315 | .258 | .228 | .194 | .165 | .143 | .129 | .114 |

| | | |
|---|---|---|
| 1 square foot, wooden beam construction, planked over, or ceiled, | as flooring | .083 |
| | as ceiling | .104 |
| 1 square foot, fireproof construction, floored over, | as flooring | .122 |
| | as ceiling | .145 |
| 1 square foot, single window | | 1.215 |
| 1 square foot, single skylight | | 1.03 |
| 1 square foot, double window | | .572 |
| 1 square foot, double skylight | | .621 |
| 1 square foot, vault light | | 1.43 |
| 1 square foot, door (65% wood, 35% glass) | | .572 |
| 1 square foot, door (plain) | | .414 |

It is further prescribed that these coefficients are to be increased respectively as follows:

Ten per cent. where the exposure is a northerly one, and winds are to be counted on as important factors.

Ten per cent. when the building is heated during the daytime only, and the location of the building is not an exposed one.

Thirty per cent. when the building is heated during the daytime only, and the location of the building is exposed.

Fifty per cent. when the building is heated during the winter months intermittently, with long intervals (say days or weeks) of non-heating.

From the above, Mr. Wolff has also prepared a diagram, in form similar to that here given (Fig. 2), which serves to present the data graphically in the most comprehensive manner for practical application.

By the use of this diagram it is possible to determine the total loss of heat by transmission from a given room, and to thereby ascertain the amount of heat, as measured in heat units, that must be continuously supplied to the room to make good this loss and maintain the temperature. But this does not cover the additional heat necessary on account of change of air for the purposes of ventilation.

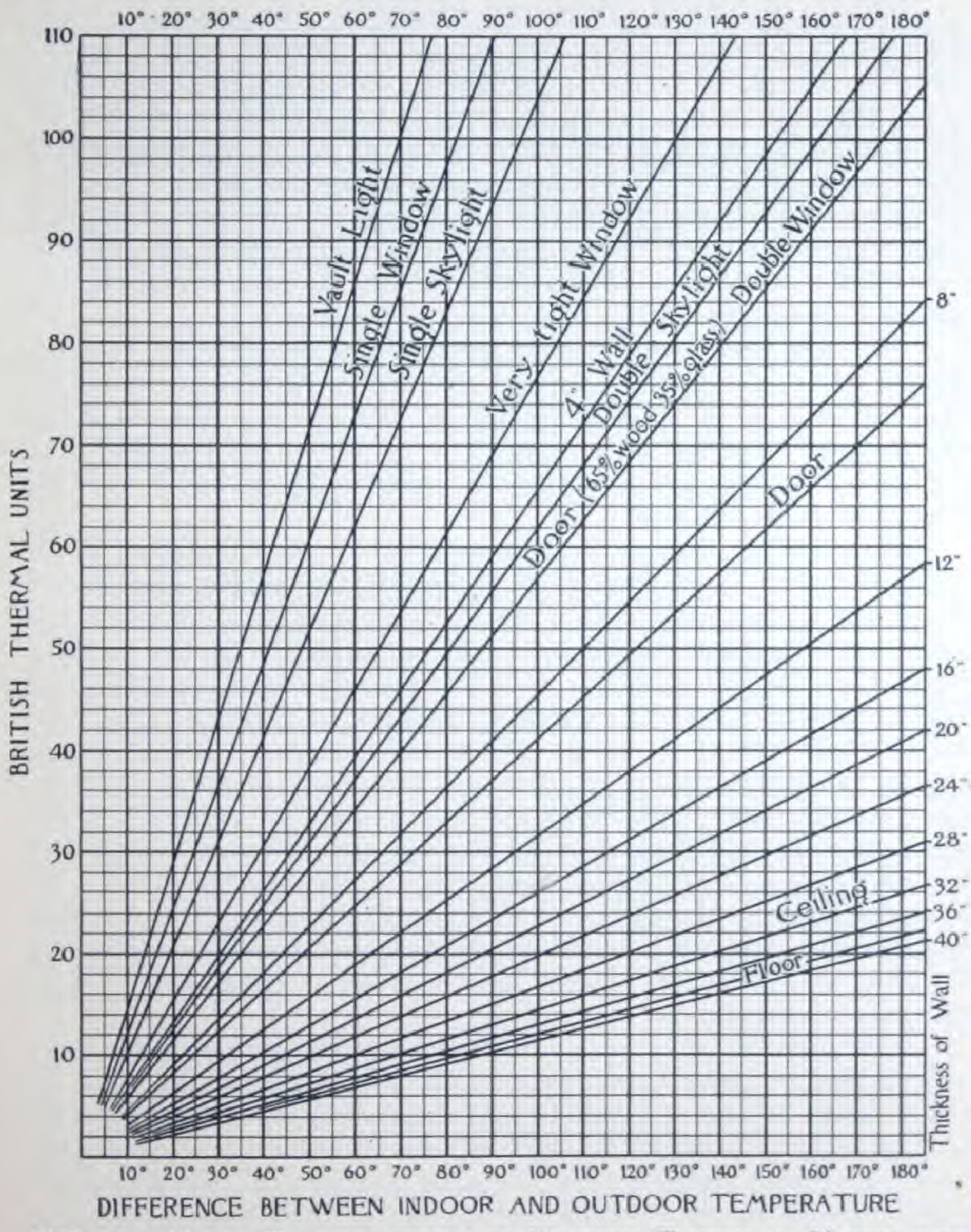



FIG. 2. HEAT TRANSMITTED, IN BRITISH THERMAL UNITS, PER HOUR PER SQUARE FOOT OF SURFACE.

# VENTILATION AND HEATING

EFFECT OF VENTILATION ON HEATING. The reduction of temperature within a building is the result, first, of the combined losses of heat by conduction through and radiation from windows, doors, walls, floors and ceilings, as has been pointed out; and, second, by direct leakage or escape of air at the temperature of the room. The former varies directly with the difference between the internal and the external temperatures, and is proportional thereto. Wherever the blower system is used, the cost of heat supply, to make good this loss, is measured by the difference between the average temperature of the air within the room and that of the air as it is first discharged into the room from the heating apparatus, disregarding losses in transit from the apparatus.

The loss by leakage and escape of air is measured directly by the difference between indoor and outdoor temperatures, this representing the heat added to the air, which serves no directly useful purpose in heating. It is thus evident that with a constant volume of air the expenditure for heating will be indicated by the loss by the first method, and that for ventilation by the loss of warm air escaping by the second means.

When heating alone, as the ultimate object of the introduction of the Sturtevant System, is considered, it will be found that to maintain a temperature of 70° with outdoor temperature at zero, a change of air every sixteen minutes with an entering temperature of about 140° will represent a fair average in the northern portions of this country. Under these circumstances, disregarding the weight or density of the air at different temperatures, the difference between 70° and 140° will represent the loss by radiation and conduction. If with the same entering temperature the loss is greater, the temperature of the room will be lower, and vice versa. There is thus lost $\frac{70}{140}$, or one-half, of all the heat by this means; or if, for ready comparison, we represent each degree as a unit, not of heat but merely of relative measurement, there will have been lost 70 units. If, in a given time, a given volume of air is delivered to the room, its cost in total heat expenditure must be measured by the number of degrees its temperature has been raised above zero; that is, upon our basis of comparison, it will be equivalent to 140 units.

In the given time all of this air must escape at the temperature of the room, which is here 70°; hence the loss by this means will also be 70 units, and it can by no means be reduced except by deliberately decreasing the volume of air admitted, or by increasing the difference between internal and external temperatures. It is evident that with a fan running at constant speed and delivering a stated volume of air, the ventilation may be reduced by returning a portion of the air from the building, and the expenditure likewise lessened. The loss by

radiation and conduction, on the other hand, can be reduced by sufficient, although perhaps extravagant, expenditure for double or triple sash, thicker walls, back plaster, sheathing paper, and the like.

If, with the same air change, all the air should be returned from the building on the impossible assumption that there is no leakage, the temperature of the air admitted would still require to be 140°, and the loss by radiation and conduction would be the same, namely 70 units, but the leakage would be reduced to zero, and the total heat expenditure would be only one-half of that in the former instance.

If, now, under the same conditions of construction the building be fully occupied and the demands of ventilation be considered, it will be necessary to reduce the time of air change, i.e., increase the volume of air delivered. If the building be occupied as a school, with the ordinary ratio of about 250 cubic feet of room-space per pupil, it will be necessary, in order to supply 30 cubic feet of air per minute per pupil, to furnish a volume equivalent to changing the air once in about eight minutes.

With outdoor air still at zero and an indoor temperature to be maintained at 70°, it is evident that with the air supply just double that in the first instance (as would be true with the eight-minute change), its temperature need not be as high; in fact, as the real heating power of the admitted air is measured only by its temperature above 70°, which was $140 - 70 = 70°$ in the former instance, there will now be required, with double the air volume, only one-half the temperature increment, or 35°.

Compared by units, it will, therefore, be necessary to provide for the loss by leakage twice as many as before, that is, $2 \times 70 = 140$. To these must be added those supplied for radiation and conduction, which, with twice the volume of air and an increment of 35°, will still equal 70 units, or a total of $140 + 70 = 210$ units. But as the volume is double, its temperature, volume for volume, as compared with the first illustration, will be $210 \div 2 = 105°$, which evidently equals $70 + 35$ degrees.

To summarize, there will now be required 210 units as against 140 units in the first instance, an increase of 50 per cent., and three times as many as under the assumed condition of all return air to the apparatus, — while the temperature of the admitted air stands at 140° for the sixteen-minute and 105° for the eight-minute change.

These propositions are more clearly presented in the accompanying diagram, Fig. 3, of the cost of heating and ventilation, with the relative cost of heating alone, and of temperatures of entering air. Of course, it is impossible to make

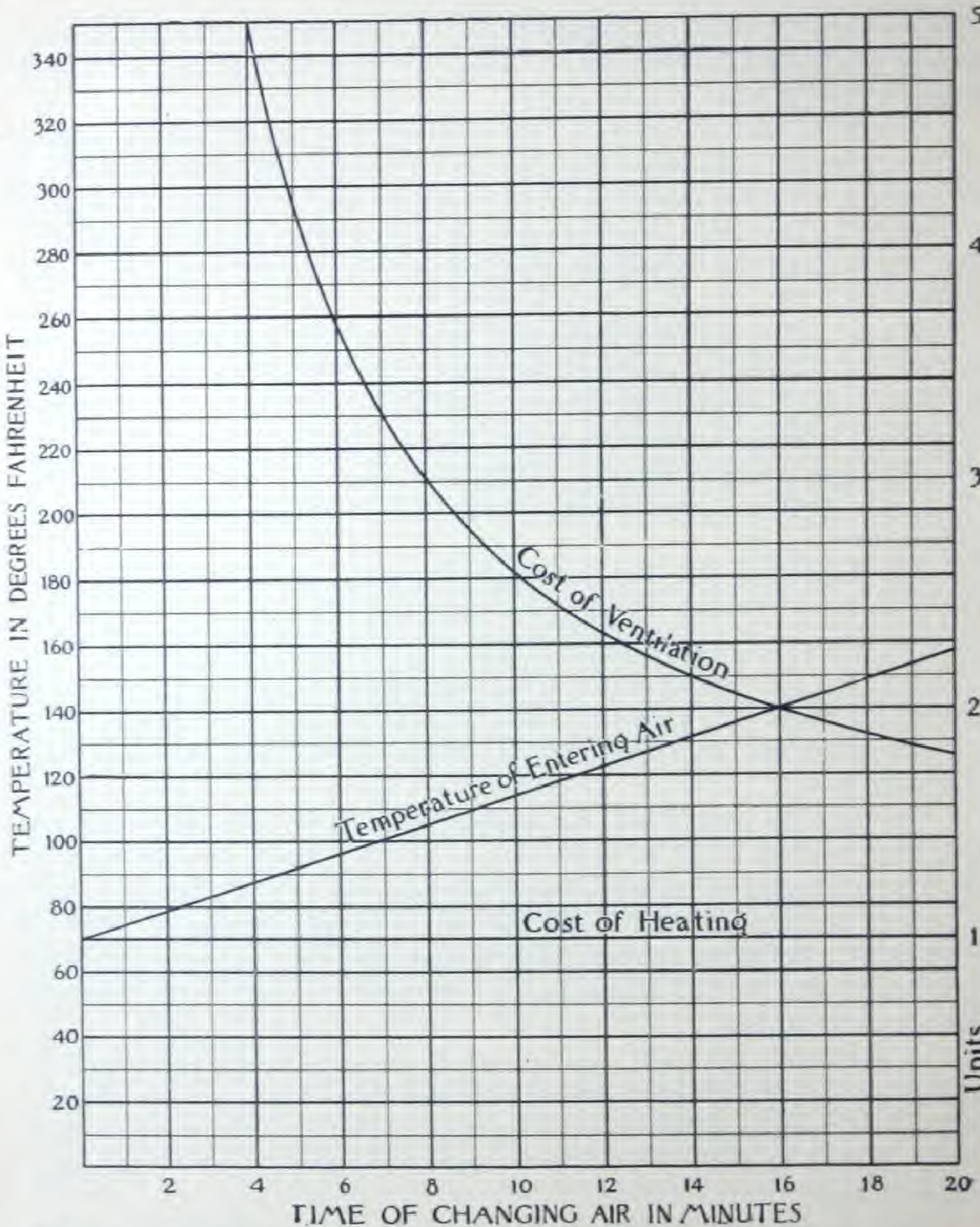



FIG. 3. RELATIVE COSTS OF HEATING AND VENTILATION, WITH DIFFERENT TEMPERATURES OF ENTERING AIR.

this accurately applicable to all classes of buildings, as the lines are based upon the proportions previously given, which can only be said to represent a fair average. They do make clear, however, the approximate relations existing between the cost of heating (which is constant) and the cost of ventilation (which increases with the volume of air admitted), and serve to make evident the necessity of increased boiler capacity where improved ventilation is introduced. As here represented, the individual cost of ventilation is additional to that for heating, and is to be measured above the line of cost for heating. The relative cost for both heating and ventilation combined is to be measured from the base line.

HEATING CALCULATIONS. The thermal value, or heating power, of water and of steam has been found by elaborate experiments, and the results are embodied in complete and convenient tables. By a proper understanding and use of such tables, in connection with tables of the properties of air, ready calculations may be made in all matters relating to steam heating. The following tables, No. 2, Of the Properties of Saturated Steam, and No. 3, Of the Number of Thermal Units Contained in One Pound of Water, embody the principal data. Table No. 1, Of the Properties of Air, Vapor and Saturated Mixtures of Air and Vapor, has already been presented. Figures between those given in the tables may be obtained with sufficient accuracy by interpolation.

It is customary to base calculations of heating capacity upon the number of pounds or cubic feet of air that can be heated by the condensation of one pound of steam. The specific heat of air under constant pressure is .2379 compared with water as a standard. That is to say, the heat-absorbing power of air is about one-fourth that of water, and the amount of heat required to heat one pound of water through 1° F, will heat $\frac{1}{.2379}=4.2034$ pounds of air, through the same increment. The total heat and sensible temperature of steam increase with the pressure, as seen by Table No. 2. Upon condensation, steam gives up its latent heat and is resolved into water having the same temperature as the steam from which it was condensed. Hence, the heating power of a pound of steam of a given pressure is expressed by the heat thus given out, i.e., by the total number of units of heat in the original steam less the number in the final water of condensation.

Taking a pressure of 86 pounds above vacuum, for instance, the temperature of the steam, as well as that of the water from which it was evaporated, is 316.84°, while the total heat in the steam, as measured in heat units, is 1,210.58 units (by column 4, Table No. 2). The 890.69 units of heat (column 3) which were added to each pound of water of 316.84° temperature to evaporate it into

## TABLE No. 2.

## OF THE PROPERTIES OF SATURATED STEAM.

| Total Pressure per square inch, measured from a Vacuum. | Temperature in Degrees Fahrenheit of Steam and of the Water from which it was evaporated. | Number of British Thermal Units contained in one pound, reckoned from Zero Fahrenheit. Number required for evaporation, known as latent heat, or heat of vaporization. | Total number contained in the Steam. | Weight of one Cubic Foot of Steam in decimals of a pound. | Volume of one pound of Steam in Cubic Feet. | Relative Volume or Cubic Feet of Steam from one Cubic Foot of Water. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 102. | 1042.96 | 1145.05 | .0030 | 330.36 | 20620. |
| 2 | 126.27 | 1026.01 | 1152.45 | .0058 | 172.08 | 10720. |
| 3 | 141.62 | 1015.25 | 1157.13 | .0085 | 117.52 | 7326. |
| 4 | 153.07 | 1007.23 | 1160.62 | .0112 | 89.62 | 5600. |
| 5 | 162.33 | 1000.73 | 1163.45 | .0137 | 72.66 | 4535. |
| 6 | 170.12 | 995.25 | 1165.83 | .0163 | 61.21 | 3814. |
| 7 | 176.91 | 990.47 | 1167.90 | .0189 | 52.94 | 3300. |
| 8 | 182.91 | 986.25 | 1169.73 | .0214 | 46.69 | 2910. |
| 9 | 188.32 | 982.43 | 1171.37 | .0239 | 41.79 | 2607. |
| 10 | 193.24 | 978.96 | 1172.88 | .0264 | 37.84 | 2360 |
| 12 | 201.96 | 972.80 | 1175.54 | .0313 | 31.95 | 1988. |
| 14 | 209.56 | 967.43 | 1177.85 | .0361 | 27.63 | 1722. |
| 14.7 | 212. | 965.7 | 1178.60 | .0380 | 26.36 | 1644. |
| 16 | 216.30 | 962.66 | 1179.91 | .0413 | 24.21 | 1514. |
| 18 | 222.38 | 958.34 | 1181.76 | .0462 | 21.64 | 1350.6 |
| 20 | 227.92 | 954.41 | 1183.45 | .0511 | 19.57 | 1220.3 |
| 22 | 233.02 | 950.79 | 1185.01 | .0561 | 17.83 | 1113.5 |
| 24 | 237.75 | 947.42 | 1186.45 | .0610 | 16.39 | 1024.1 |
| 26 | 242.17 | 944.28 | 1187.80 | .0658 | 15.19 | 948.4 |
| 28 | 246.33 | 941.32 | 1189.07 | .0707 | 14.14 | 883.2 |
| 30 | 250.24 | 938.92 | 1190.26 | .0755 | 13.25 | 826.8 |
| 32 | 253.95 | 935.88 | 1191.39 | .0803 | 12.45 | 777.2 |
| 34 | 257.48 | 933.37 | 1192.47 | .0851 | 11.75 | 733.5 |
| 36 | 260.83 | 930.97 | 1193.49 | .0899 | 11.11 | 694.5 |
| 38 | 264.05 | 928.67 | 1194.47 | .0946 | 10.56 | 659.7 |
| 40 | 267.12 | 926.47 | 1195.41 | .0994 | 10.06 | 628.2 |
| 42 | 270.07 | 924.36 | 1196.31 | .1041 | 9.59 | 599.[illegible] |
| 44 | 272.91 | 922.32 | 1197.18 | .1088 | 9.18 | 573.7 |
| 46 | 275.65 | 920.36 | 1198.01 | .1134 | 8.82 | 550.4 |
| 48 | 278.30 | 918.47 | 1198.82 | .1181 | 8.47 | 529.0 |
| 50 | 280.85 | 916.63 | 1199.60 | .1227 | 8.15 | 508.5 |
| 52 | 283.33 | 914.86 | 1200.35 | .1274 | 7.85 | 490.1 |
| 54 | 285.72 | 913.13 | 1201.09 | .1320 | 7.58 | 472.9 |
| 56 | 288.05 | 911.46 | 1201.80 | .1366 | 7.32 | 457.0 |
| 58 | 290.32 | 909.83 | 1202.49 | .1411 | 7.08 | 442.4 |

## TABLE No. 2.

### OF THE PROPERTIES OF SATURATED STEAM.—Continued.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 60 | 292.52 | 908.25 | 1203.16 | .1457 | 6.86 | 428.5 |
| 62 | 294.66 | 906.70 | 1203.81 | .1502 | 6.66 | 415.6 |
| 64 | 296.75 | 905.20 | 1204.45 | .1547 | 6.46 | 403.5 |
| 66 | 298.79 | 903.73 | 1205.07 | .1592 | 6.28 | 392.1 |
| 68 | 300.78 | 902.30 | 1205.68 | .1637 | 6.10 | 381.3 |
| 70 | 302.72 | 900.90 | 1206.27 | .1682 | 5.95 | 371.2 |
| 72 | 304.62 | 899.53 | 1206.85 | .1726 | 5.80 | 361.7 |
| 74 | 306.47 | 898.19 | 1207.41 | .1770 | 5.65 | 352.6 |
| 76 | 308.29 | 896.88 | 1207.97 | .1814 | 5.51 | 344.1 |
| 78 | 310.07 | 895.59 | 1208.51 | .1858 | 5.34 | 336.0 |
| 80 | 311.81 | 894.33 | 1209.04 | .1901 | 5.26 | 328.3 |
| 82 | 313.52 | 893.09 | 1209.56 | .1945 | 5.14 | 320.9 |
| 84 | 315.19 | 891.88 | 1210.07 | .1989 | 5.03 | 313.9 |
| 86 | 316.84 | 890.69 | 1210.58 | .2032 | 4.92 | 307.2 |
| 88 | 318.45 | 889.52 | 1211.07 | .2075 | 4.82 | 300.8 |
| 90 | 320.04 | 888.38 | 1211.55 | .2118 | 4.72 | 294.7 |
| 92 | 321.60 | 887.25 | 1212.03 | .2161 | 4.63 | 288.9 |
| 94 | 323.13 | 886.14 | 1212.49 | .2204 | 4.54 | 283.3 |
| 96 | 324.63 | 885.04 | 1212.95 | .2245 | 4.44 | 278.0 |
| 98 | 326.11 | 883.97 | 1213.40 | .2288 | 4.37 | 272.8 |
| 100 | 327.57 | 882.91 | 1213.85 | .2330 | 4.29 | 267.9 |
| 105 | 331.11 | 880.34 | 1214.93 | .2434 | 4.11 | 256.5 |
| 110 | 334.52 | 877.86 | 1215.97 | .2538 | 3.94 | 246.0 |
| 115 | 337.81 | 875.47 | 1216.97 | .2640 | 3.79 | 236.3 |
| 120 | 340.99 | 873.15 | 1217.94 | .2743 | 3.65 | 227.6 |
| 125 | 344.07 | 870.90 | 1218.88 | .2843 | 3.52 | 219.7 |
| 130 | 347.06 | 868.73 | 1219.79 | .2942 | 3.40 | 212.3 |
| 135 | 349.95 | 866.62 | 1220.68 | .3040 | 3.29 | 205.4 |
| 140 | 352.77 | 864.57 | 1221.53 | .3139 | 3.19 | 199.0 |
| 145 | 355.50 | 862.57 | 1222.37 | .3239 | 3.09 | 193.0 |
| 150 | 358.16 | 860.62 | 1223.18 | .3340 | 2.99 | 187.5 |
| 160 | 363.28 | 856.87 | 1224.74 | .3521 | 2.84 | 177.3 |
| 170 | 368.16 | 853.29 | 1226.23 | .3709 | 2.69 | 168.4 |
| 180 | 372.82 | 849.87 | 1227.65 | .3889 | 2.57 | 160.4 |
| 190 | 377.29 | 846.58 | 1229.01 | .4072 | 2.45 | 153.4 |
| 200 | 381.57 | 843.43 | 1230.32 | .4250 | 2.35 | 147.1 |
| 250 | 401.07 | 831.22 | 1235.73 | .5464 | 1.83 | 114. |
| 300 | 418.22 | 819.61 | 1240.74 | .6486 | 1.54 | 96. |
| 350 | 431.96 | 810.69 | 1244.58 | .7498 | 1.33 | 83. |
| 400 | 444.92 | 800.20 | 1249.09 | .8562 | 1.18 | 73. |

## TABLE No. 3.

### Of the Number of Thermal Units Contained in One Pound of Water.

| Temperature. | Number of Thermal Units | Increase. | Temperature. | Number of Thermal Units. | Increase. | Temperature. | Number of Thermal Units. | Increase. |
|---|---|---|---|---|---|---|---|---|
| 35° | 35.000 | | 155° | 155.339 | 5.034 | 275° | 276.985 | 5.107 |
| 40 | 40.001 | 5.001 | 160 | 160.374 | 5.035 | 280 | 282.095 | 5.110 |
| 45 | 45.002 | 5.001 | 165 | 165.413 | 5.039 | 285 | 287.210 | 5.115 |
| 50 | 50.003 | 5.001 | 170 | 170.453 | 5.040 | 290 | 292.329 | 5.119 |
| 55 | 55.006 | 5.003 | 175 | 175.497 | 5.044 | 295 | 297.452 | 5.123 |
| 60 | 60.009 | 5.003 | 180 | 180.542 | 5.045 | 300 | 302.580 | 5.128 |
| 65 | 65.014 | 5.005 | 185 | 185.591 | 5.049 | 305 | 307.712 | 5.132 |
| 70 | 70.020 | 5.006 | 190 | 190.643 | 5.052 | 310 | 312.848 | 5.136 |
| 75 | 75.027 | 5.007 | 195 | 195.697 | 5.054 | 315 | 317.988 | 5.140 |
| 80 | 80.036 | 5.009 | 200 | 200.753 | 5.056 | 320 | 323.134 | 5.146 |
| 85 | 85.045 | 5.009 | 205 | 205.813 | 5.060 | 325 | 328.284 | 5.150 |
| 90 | 90.055 | 5.010 | 210 | 210.874 | 5.061 | 330 | 333.438 | 5.154 |
| 95 | 95.067 | 5.012 | 215 | 215.939 | 5.065 | 335 | 338.596 | 5.158 |
| 100 | 100.080 | 5.013 | 220 | 221.007 | 5.068 | 340 | 343.759 | 5.163 |
| 105 | 105.095 | 5.015 | 225 | 226.078 | 5.071 | 345 | 348.927 | 5.168 |
| 110 | 110.110 | 5.015 | 230 | 231.153 | 5.075 | 350 | 354.101 | 5.174 |
| 115 | 115.129 | 5.019 | 235 | 236.232 | 5.079 | 355 | 359.280 | 5.179 |
| 120 | 120.149 | 5.020 | 240 | 241.313 | 5.081 | 360 | 364.464 | 5.184 |
| 125 | 125.169 | 5.020 | 245 | 246.398 | 5.085 | 365 | 369.653 | 5.189 |
| 130 | 130.192 | 5.023 | 250 | 251.487 | 5.089 | 370 | 374.846 | 5.193 |
| 135 | 135.217 | 5.025 | 255 | 256.579 | 5.092 | 375 | 380.044 | 5.198 |
| 140 | 140.245 | 5.028 | 260 | 261.674 | 5.095 | 380 | 385.247 | 5.203 |
| 145 | 145.275 | 5.030 | 265 | 266.774 | 5.100 | 385 | 390.456 | 5.209 |
| 150 | 150.305 | 5.030 | 270 | 271.878 | 5.104 | 390 | 395.672 | 5.216 |

steam will, upon the condensation of that steam, reappear as available for heating. The standard unit of heat is equivalent to the amount of heat necessary to raise the temperature of one pound of water through one degree Fahrenheit at its point of greatest density. A heat unit is not to be confounded with a degree of temperature, notwithstanding the fact the visible temperature of water, as expressed in degrees, and the total heat, as stated in heat units, are indicated by very nearly the same figures (see Table No. 3), the variation being due to the altered density of the water.

If, therefore, one heat unit will raise the temperature of one pound of water through one degree under stated conditions, 890.69 units — given out by the condensation of one pound of steam of 86 pounds pressure — will heat 890.69 pounds of water through one degree. Allowing for the difference in specific heat, this same heat expenditure would result in raising the temperature of $890.69 \times 4.2034 = 3{,}743.926$ pounds of air through one degree. Supposing the air to be originally at a temperature of $32^\circ$, then, if dry, its weight per cubic foot would be .0807 pounds (column 3, Table No. 1), and 3,743.926 pounds would be equivalent to $\frac{3743.926}{.0807} = 46{,}393$ cubic feet. Upon this basis Table No. 4 has been calculated, it being assumed that the water of condensation is not cooled below the temperature of the steam from which it is condensed. The amount of heat that would thus increase the temperature of the volume of air through one degree would raise the temperature of half the amount through twice as many degrees, and so on in like proportion, so far as the initial difference between the temperature of the air and of the steam will permit.

As an illustration of the application of Table No. 4, suppose it is desired to heat 500,000 cubic feet of dry air from $32^\circ$ to $92^\circ$, or through an increment of $60^\circ$, with steam of 75 pounds absolute pressure. By Table No. 4 it is seen that one pound of steam at the given pressure will raise 46,736 cubic feet of air at $32^\circ$ through one degree, and consequently $\frac{46736}{60} = 778.93$ cubic feet through $60^\circ$. To heat 500,000 cubic feet through $60^\circ$ there will, therefore, be required $\frac{500000}{778.93} = 641.9$ pounds of steam. Of course, it must be evident from the preceding the calculation has only been made of the amount of heat directly applied for heating. If the water of condensation can be returned to the boiler without material reduction of temperature, there need be but little loss in this direction; but where it is thrown away, as is frequently the case with exhaust steam, the total heat expenditure for producing the steam from the feed water at its initial temperature must be made the basis of calculation. The horizontal column at the bottom of the table indicates that the presence of vapor in the air, even to saturation, has but slight effect upon the values at low or moderate temperatures.

## TABLE No. 4.

### OF THE NUMBER OF CUBIC FEET OF DRY AIR THAT MAY BE HEATED THROUGH 1° (F.) BY THE CONDENSATION OF ONE POUND OF STEAM.

| Steam Pressure above Vacuum. | INITIAL TEMPERATURE OF AIR. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0° | 12° | 22° | 32° | 42° | 52° | 62° | 72° | 82° | 92° | 102° |
| 15 | 46,946 | 48,173 | 49,225 | 50,262 | 51,279 | 52,270 | 53,300 | 54,299 | 55,343 | 56,336 | 57,371 |
| 25 | 46,014 | 47,217 | 48,249 | 49,265 | 50,262 | 51,233 | 52,243 | 53,222 | 54,239 | 55,218 | 56,233 |
| 35 | 45,349 | 46,535 | 47,551 | 48,553 | 49,535 | 50,492 | 51,488 | 52,452 | 53,454 | 54,419 | 55,420 |
| 45 | 44,823 | 45,994 | 46,999 | 47,989 | 48,834 | 49,907 | 50,890 | 51,844 | 52,834 | 53,788 | 54,777 |
| 55 | 44,391 | 45,551 | 46,546 | 47,527 | 48,488 | 49,413 | 50,399 | 51,344 | 52,325 | 53,270 | 54,248 |
| 65 | 44,002 | 45,140 | 46,139 | 47,110 | 48,064 | 48,993 | 49,956 | 50,907 | 51,866 | 52,831 | 53,774 |
| 75 | 43,665 | 44,806 | 45,785 | 46,746 | 47,695 | 48,616 | 49,575 | 50,504 | 51,469 | 52,399 | 53,362 |
| 85 | 43,361 | 44,493 | 45,466 | 46,424 | 47,361 | 48,279 | 49,230 | 50,153 | 51,111 | 52,034 | 52,990 |
| 95 | 43,084 | 44,209 | 45,176 | 46,127 | 47,060 | 47,969 | 48,905 | 49,832 | 50,784 | 51,701 | 52,652 |
| 105 | 42,829 | 43,972 | 44,908 | 45,854 | 46,780 | 47,684 | 48,626 | 49,538 | 50,485 | 51,395 | 52,339 |
| Per ct. of above amounts that will be heated 1° if air is saturated. | 99.8 | 99.6 | 99.4 | 99.0 | 98.6 | 98.0 | 97.1 | 96.0 | 94.5 | 92.5 | 90.1 |

From a knowledge of the number of units of heat required, or the total weight of steam necessary per unit of time for any given building, it is a simple matter to deduce the size and capacity of the boiler to be provided. A proper understanding of the relative values of high and low pressure steam will result in due consideration being given to this factor in deciding upon the boiler capacity.

EFFICIENCY OF HEATING SURFACE. The character and efficiency of the heating surface does not enter into such calculations as have just been described. The number of heat units necessary to be transmitted to the air in a given time being known, it rests with the designer to determine the amount and arrangement of heating surface to be provided to secure the desired results. Obviously, the higher the efficiency of such surface, i.e., the greater the number

of pounds of steam that may be condensed per hour per square foot of heating surface, the smaller and, other things being equal, the less expensive that surface will be. The efficiency of any heating surface must be directly dependent, first, upon its character and arrangement, and, second, upon the volume of air passing across it. Under the conditions of an open-pipe radiator with air surrounding it at an average temperature of 60°, Robert Briggs gives, as the factor accepted by him, a loss of 1.8 units per hour per square foot of heating surface per degree difference of temperature between the steam inside and the air outside. Other writers and investigators give somewhat varying values. Taking the air temperature at 60° and the temperature of exhaust steam at 216° (nearly), the difference would be 156°, and the number of units given out per hour per square foot of heating surface would be $156 \times 1.8 = 280.8$ units. The latent heat of steam at atmospheric pressure is 965.7 (column 3, Table No. 2), therefore, $\frac{280.8}{965.7} = .29$ pounds of steam would be condensed per hour per square foot of heating surface. A similar calculation gives .44 pounds with steam at 70 pounds gauge pressure. Direct experiments made at the works of this Company, on a series of pipes exposed to air of about 60° and strung around a room at about three inches from a cold brick wall, showed a condensation somewhat greater than this, but probably due to several modifying influences, particularly that of the cold wall.

Under such an arrangement a large proportion of the heat is given up by radiation to the air and surrounding objects, the remainder being conducted directly to the air which passes across the surface. These two means exist as the opportunities for the communication of heat — convection, so-called, being only a form of conduction. Radiation takes place in straight lines, so that a given amount of surface becomes less efficient as a *radiator*, as it is massed in such form as to interfere with the radiation of heat directly to the surrounding objects. Air is a very poor absorber of radiant heat, so that it is evident that the efficiency of a massed coil can only be increased by giving it greater opportunity for conduction of heat from its surface to the air with which it is in contact. In other words, by increasing the air flow across this surface in such a way that the heat may be almost literally wiped off and carried to a point where the air may advantageously part with it.

Upon this principle the hot-blast apparatus is designed and its high efficiency secured. Many factors enter to determine the form, proportions and general arrangement of the heating surface, as well as the permissible air volume, in such an apparatus. Appreciating the necessity of the most reliable data, and knowing that nothing of the kind existed, this Company conducted an exhaustive series

of experiments, covering several winter months, upon various forms of specially-constructed apparatus, to obtain all necessary data for the correct design and construction of its apparatus, as well as the intelligent application of the same. By means of formulæ derived from these experiments, we are enabled to make most accurate determinations of resulting temperatures and steam condensation under given conditions, as well as to design new work with the most positive assurance of success.

Among other results it was shown that in the Sturtevant Heaters a condensation was ordinarily obtained of 2 to 2½ pounds of high-pressure steam per hour per square foot of heating surface. Of course, the amount of condensation is dependent upon numerous variables,—the steam pressure, the specific arrangement of the heating surface, the initial temperature and the velocity of the air. Compared with the previous figures upon direct radiation, the enormous gain in efficiency is evident. A conservative estimate would, therefore, indicate the Sturtevant Heater to be at least three to five times more efficient than an open-pipe radiator.

HEATING SURFACE REQUIRED. The total amount of heat necessary, as measured in heat units, having been determined by calculation and the efficiency of the selected form of heating surface being known, it is a comparatively simple matter to decide upon the amount of heating surface required for any given building. But all the conditions must be taken into consideration; the calculations must be made for the minimum winter temperature, the steam pressure must be known, and it must be decided whether the air is to be taken entirely from out-of-doors to the heating apparatus, or to some extent returned from the building. As already shown, this latter practice is conducive to economy, but, of course, is not to be employed except where heating is the primary object in the introduction of the system, or the normal supply of air is very large per capita.

While quantity of heating surface is of the utmost importance, its arrangement is hardly less important. It is not enough to have a given number of lineal feet of steam coils, or pipes spaced a given distance on centres, but it is further necessary to have the sections or groups of pipes combined in such form that there may be sufficient free area between the pipes to allow of the ready passage of the air handled by the fan, while the total number of pipes with which a given particle of air comes in contact in its passage through the heater must be such as to secure the requisite rise in temperature of that air. Those who do not possess extended experience in such matters are very apt to so

arrange their heating surface as to greatly reduce its efficiency, with resulting failure in the heating of the building in which it is installed.

One of the important objects in view in conducting the tests on Sturtevant Heaters, previously alluded to, was to determine definitely the influence of different arrangements of heating surface of the same general character and to ascertain the form in which it could be rendered most efficient. In other words, to place this Company in a position to specify with certainty of the results to be accomplished, the most economical arrangement of the heating surface, thereby decreasing the first cost of the apparatus without impairing or affecting its efficiency.

It is obviously impossible to give in practical form all of the data thus obtained, but a statement of the general practice, as it now obtains, may at least guide somewhat in the rough planning of heating and ventilating systems, and serve reasonably well as a check upon calculations made by the methods already described.

In hot-blast heating, the proportional heating surface is generally expressed in the number of net cubic feet in the building for each lineal foot of one inch steam pipe in the heater. On this basis, in factory practice, with all of the air taken from out-of-doors, there is generally allowed from 100 to 150 cubic feet of space per foot of pipe, according as exhaust or live steam is used, the term "live steam" being taken in its ordinary sense as indicating steam of about 80 pounds pressure. If practically all of the air is returned from the building, these figures will be raised to about 140, as the minimum, and possibly 200 cubic feet, as the maximum, per foot of pipe. Of course, the larger the building in cubic contents the less its wall and roof exposure per foot of cubic space, and consequently the less the loss of heat and the smaller the heater relatively to the cubic contents. In such buildings, used for manufacturing purposes, where the occupants are usually well scattered, an air change once in fifteen to twenty minutes represents the general practice, but in public and similar buildings this change is of necessity reduced to once in seven to twelve minutes. Owing to the increased loss of heat by leakage or ventilation under such conditions, and also to the demand for a slightly higher temperature than in the shop, the allowance is dropped to from 70 or 75 to 125 cubic feet of space per foot of pipe, for all of the air is taken from out-of-doors and low-pressure steam is usually employed. The great range in all of these figures must make evident the influence of the size, construction and uses of a building upon the size of the apparatus required, and show the necessity of extended experience for the proper designing of any system of heating and ventilation.

VALUE OF EXHAUST STEAM. Most important to every manufacturer is the complete utilization of his exhaust steam, for it usually has a value as a heating medium of very nearly 97 per cent. of ordinary high-pressure steam. It is obviously unwise to employ live steam for heating when exhaust steam is at hand or even at some distance, for the expenditure for the conducting pipe for such waste steam will almost always be warranted.

In many systems of direct radiation it is more or less difficult to make use of the exhaust, but the Sturtevant Heater has been designed with this special purpose in view. It is, furthermore, arranged with one or more special sections, in which may be condensed the exhaust steam from the small engine which is usually provided for driving the fan.

Although the total heat (measured in heat units) of exhaust steam and of live steam of 80 pounds is very nearly the same, the difference in actual temperature is such — exhaust steam averaging about 220°, while steam of 80 pounds is about 323° — that there is a marked difference in the rate at which they give up their heat when enclosed in steam pipes across which air is caused to circulate. This rate of transmission is proportional to the difference in temperature between the steam within and the air outside the pipe, and, therefore, exhaust steam requires for the condensation of a given weight of steam in a unit of time a larger area of surface than live steam.

Furthermore, exhaust steam being less dense than live, it must require a larger pipe to convey the same weight. The proper proportioning of the areas of steam-conducting pipes, according to the pressure, seldom receives sufficient attention. The accompanying table, No. 5, is therefore presented to show the amount of steam of given pressure that will flow per minute through pipes of various sizes with a loss of only one pound of pressure. From this may be easily determined with sufficient accuracy, the size of steam pipe required to conduct a given weight of steam of known pressure.

In considering the introduction of a special engine for driving the fan of a heating apparatus, it should be clearly realized that a certain amount of steam being required for supply to the heater, the passage of that steam through the engine on its way to the heater entails very little loss in its heating power,— so little, in fact, that the actual expense of driving the fan may be disregarded and the steam-engine cylinder may be looked upon as merely an enlargement of the steam pipe. Evidently this feature of this system has its influence on the relative cost of driving the fan by engine, or by electric motor, for, in the employment of the latter there is no incidental return whereby the cost of power is reduced.

## TABLE No. 5.

### Of Weight of Steam in Pounds per Minute that will Flow through Pipes of Given Diameter with Loss of One Pound of Pressure.

| Initial Gauge Pressure in Lbs. per Sq. In. | DIAMETER OF PIPE IN INCHES. LENGTH OF EACH = 240 DIAMETERS. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ¾ | 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 8 | 10 |
| 1 | 1.16 | 2.07 | 5.7 | 10.27 | 15.45 | 25.38 | 46.85 | 77.3 | 115.9 | 211.4 | 341.1 |
| 10 | 1.44 | 2.57 | 7.1 | 12.72 | 19.15 | 31.45 | 58.05 | 95.8 | 143.6 | 262.0 | 422.7 |
| 20 | 1.70 | 3.02 | 8.3 | 14.94 | 22.49 | 36.94 | 68.20 | 112.6 | 168.7 | 307.8 | 496.5 |
| 30 | 1.91 | 3.40 | 9.4 | 16.84 | 25.35 | 41.63 | 76.84 | 126.9 | 190.1 | 346.8 | 559.5 |
| 40 | 2.10 | 3.74 | 10.3 | 18.51 | 27.87 | 45.77 | 84.49 | 139.5 | 209.0 | 381.3 | 615.3 |
| 50 | 2.27 | 4.04 | 11.2 | 20.01 | 30.13 | 49.48 | 91.34 | 150.8 | 226.0 | 412.2 | 665.0 |
| 60 | 2.43 | 4.32 | 11.9 | 21.38 | 32.19 | 52.87 | 97.60 | 161.1 | 241.5 | 440.5 | 710.6 |
| 70 | 2.57 | 4.58 | 12.6 | 22.65 | 34.10 | 56.00 | 103.37 | 170.7 | 255.8 | 466.5 | 752.7 |
| 80 | 2.71 | 4.82 | 13.3 | 23.82 | 35.87 | 58.91 | 108.74 | 179.5 | 269.0 | 490.7 | 791.7 |
| 90 | 2.83 | 5.04 | 13.9 | 24.92 | 37.52 | 61.62 | 113.74 | 187.8 | 281.4 | 513.3 | 828.1 |
| 100 | 2.95 | 5.25 | 14.5 | 25.96 | 39.07 | 64.18 | 118.47 | 195.6 | 293.1 | 534.6 | 862.6 |
| 120 | 3.16 | 5.63 | 15.5 | 27.85 | 41.93 | 68.87 | 127.12 | 209.9 | 314.5 | 573.7 | 925.6 |

DETERMINATION OF FAN CAPACITY. In the case of a factory, or building of similar construction and uses, to be heated by the blower system, the matter of heating is usually considered of most importance, and, therefore, the exact average air change is first to be decided upon, a matter largely dependent upon sound judgment. As already stated, this ranges from fifteen to twenty minutes, according to circumstances. But no matter what the average time of change, certain exposed rooms should receive a larger volume of air than their proportional cubic contents would demand; on the other hand, well-protected and interior rooms demand a much smaller supply. If all the rooms are not to be heated to the same temperature, a further correction is to be made.

It is to be noted, however, that a stated increase in the air supply to a given room will not produce a proportional increase in its temperature. In the light of the preceding remarks upon the effect of ventilation on heating, it must be evident that, the temperature of the entering air remaining the same, if its volume be doubled the loss by leakage of air will be doubled also, while the

normal loss by conduction and radiation will remain the same, so long as the temperature of the room does not change. But naturally the room temperature will rise, causing a still further loss of heat by leakage, because of the higher temperature of the increased volume, whereby more than twice as many heat units escape per minute. On the other hand, the transmission loss will have become greater only in proportion to the increased difference between indoor and outdoor air.

It is, therefore, evident that some means is necessary by which special allowance may be made in the air volumes delivered to those rooms in which temperatures are to be maintained that differ from that assumed as the average of the building. By a process of reasoning, similar to that previously employed in discussing the effect of ventilation on heating, a series of factors may be determined which will aid in the ready solution of heating and ventilating problems in which a change of temperature is dependent upon a change in the air volume supplied.

The process can best be explained algebraically, and then illustrated by some practical examples. If we designate by $x$ the temperature of the entering air under certain conditions, and by $y$ the difference between the temperature maintained indoors and that existing out-of-doors, it is evident, upon the basis previously employed, that the total losses by leakage and by transmission would be respectively represented thus:

$$\text{Leakage} = \frac{y}{x} \times x = y$$

$$\text{Transmission} = \frac{x-y}{x} \times x = x - y$$

If now, with the same entering temperature is should be desired to maintain a difference between indoors and outdoors different from $y$ and expressed by $z$ then the loses would be:

$$\text{Leakage} = \frac{z}{x} \times x = z$$

$$\text{Transmission} = \frac{x-z}{x} \times x = x - z$$

But, whereas, in the first instance the transmission loss was indicated by $x-y$ the available supply for this purpose is now represented by $x-z$. Whether this amount is sufficient will depend upon the relative values of $y$ and $z$, and evidently the total supply in units necessary to meet the loss by transmission under the new conditions will be $\frac{z}{y}(x-y)$ while the volume of entering air at the

same temperature as before will have to be $\dfrac{\dfrac{z}{y}\ (x-y)}{x-z} = \dfrac{z\ (x-y)}{y\ (x-z)}$ times that in the first case.

The loss by leakage will, on the other hand, be altered in the proportion of $\dfrac{z}{y}$ due to the changed difference between indoor and outdoor temperature, further modified by the changed volume expressed by the proportion of $\dfrac{\dfrac{z}{y}\ (x-y)}{x-z}$ so that the total loss will be represented by

$$\text{Leakage} = \frac{z}{y} \times \frac{\dfrac{z}{y}\ (x-y)}{x-z} \times y = \frac{\dfrac{z^2\ y}{y^2}(x-y)}{x-z} = \frac{z^2\ (x-y)}{y\ (x-z)}$$

For the sake of illustration let us now take the case of a factory in which the air supply at a temperatue at 140° is of sufficient volume to change that within the building every 16 minutes and to maintain therein a temperature of 70°, the outdoor temperature being at 0°. Under these conditions $x = 140,°$ $y = 70°$ and

$$\text{Leakage} = \frac{y}{x} \times x = \frac{70}{140} \times 140 = 70$$

$$\text{Transmission} = \frac{x-y}{x} \times x = \frac{140-70}{140} \times 140 = 70$$

If now, it be desired to maintain the building or any room within it at 80° —which would represent $z$ in the formula, then

$$\text{Leakage} = \frac{z}{x} \times x = \frac{80}{140} \times 140 = 80$$

$$\text{Transmission} = \frac{x-z}{x} \times x = \frac{140-80}{140} \times 140 = 60$$

and the formula $\dfrac{z\ (x-y)}{y\ (x-z)}$ becomes $\dfrac{80\ (140-70)}{70\ (140-80)} = \dfrac{80\ (70)}{70\ (60)} = \dfrac{5,600}{4,200} = 1.33$

That is, 1.33 times as much air will be required to maintain an internal temperature of 80° as one of 70°. It is evident that this is a relative value, and is not dependent upon the original time for air change, and may, therefore, be applied relatively even if the time of change is not known. Under the stated conditions, however, the air volume necessary to maintain a temperature of 80° would be equivalent to air change once in 12 minutes.

The results of a series of calculations by this method, on the basis of a given volume of air at 140° being capable of heating the given building to various temperatures from 30° to 110° are represented by the accompanying curves (Fig. 4), from which may be read the factor to be employed for any given difference in temperature between indoor and outdoor air, each curved line representing factors for any basis temperature at which the given volume at 140° will maintain the building, the factor 1 applying when the basis temperature as indicated on the curve is to be maintained. For instance, if the heating apparatus is to be based upon the relative size required to maintain a difference of temperature of 70°, all factors will be read from the curve marked 70°, and the factor for any other difference, as 80°, will be obtained by following up the vertical line above the temperature until it intersects the curve of 70° and then reading the value at the left. Of course, the factors hold only for the specified temperature of entering air, but similar sets of curves may be readily developed by the same method for other temperatures. As the curves are worked out for differences in temperature, it must be evident that to obtain, for instance, the factor for a basis temperature of 20° below zero outside and 70° inside, the curve for the total difference, viz., 90°, must be used.

If the contents of the various rooms of the building have been tabulated, the factors thus obtained may be most readily applied by simply multiplying by them respectively the contents of such rooms as are to be heated to the temperatures to which they correspond and then proportioning fan, pipe and flue area relatively to their corrected contents.

Under the following illustrative conditions of contents and desired temperatures, with outdoor temperature of 0°, the factors would be applied to make the apparent relation of contents as shown:

| Capacity of Room in Cubic Feet. | Desired Temperature. | Factor. | Relative Capacity of Room in Cubic Feet. |
|---|---|---|---|
| 65,000 | 60° | .75 | 48,750 |
| 30,000 | 90° | 1.8 | 54,000 |
| 95,000 | 40° | .4 | 38,000 |
| 45,000 | 70° | 1. | 45,000 |
| 50,000 | 50° | .55 | 27,500 |
| 75,000 | 80° | 1.33 | 100,000 |
| 360,000 | | | 313,250 |

Hence, if it is estimated or known that a given air change will heat the entire structure to 70°, it will require only $\frac{313250}{360000} = .87$ as much air supply per unit of time to accomplish the desired results as above specified. The vast difference

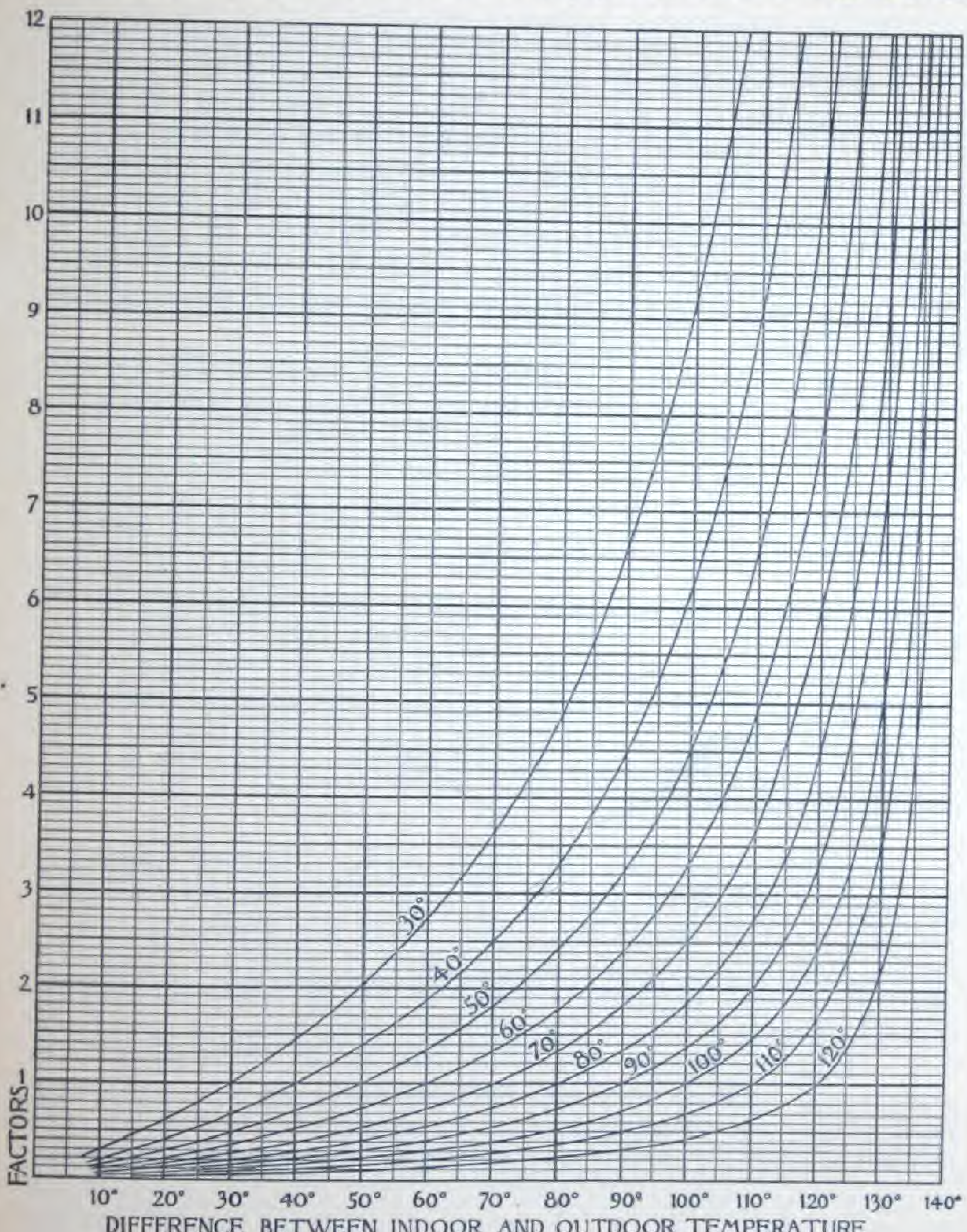



FIG. 4. FACTORS FOR PROPORTIONING AIR SUPPLY.

between requirements at high and low temperatures is evident in the factors for 40° and 90°, the latter being 4.5 times the former. If carried to its limits this method of calculation will show no air change to be required at zero and an infinite change to maintain the same temperature as that of the entering air.

Of course, it must be understood that corrections for exposure and materials of construction should be applied wherever possible, and that these factors are only to be employed in approximate work. The curves are, however, intended to cover average conditions, subject to individual corrections for various rooms, and as such indicate the relative air volumes required under equivalent conditions of exposure and construction.

This, then, is the method of determining the fan capacity required where the calculations are based merely upon the times of air change—the system generally adopted for factory and similar work. For public buildings and the like, where ventilation is the vital feature of the system and the number and activity of the occupants can be definitely determined, the total air supply is to be based upon the predetermined provision per head. The general allowances for various classes of buildings have already been given so that it is only necessary to decide upon the allowance to be made in the given case under consideration and multiply this by the total number of occupants. To the volume thus determined, must be added the amount to be provided for corridors, cloak and toilet rooms, and for apartments not intended for regular occupancy. The aggregate volume to be supplied should obviously be made sufficient for the maximum requirements and the system so arranged that proper distribution will be secured where the minimum supply is provided.

SELECTION OF FAN. The capacity of a fan is evidently measured by the number of cubic feet of air it can deliver per unit of time at a stated speed. The efficiency of the type of fan, therefore, enters as a determining factor in deciding upon its size. In any extended system of heating and ventilation of which the fan forms an element, it is necessary that the peripheral type of discharge be adopted in order to overcome the existing resistances of ducts and flues. The disc or propeller type, which forces the air in lines parallel to its shaft, is very inefficient where such resistances exist; but a fan wheel, either cased or open and delivering the air at its periphery in a more or less radial direction, is capable of meeting all requirements. It is evident that the primary factors entering to determine the capacity of a fan of given type, are its size and the speed at which it is driven. The volume of air delivered by a fan practically varies directly with the speed, while the air pressure created changes in propor-

tion to the square of the number of revolutions, and the power required to drive the fan varies in the ratio of the cube of the speed. That is to say, doubling the speed of a fan doubles the volume delivered (which is the measure of its capacity), increases the air pressure created to four times that previously existing, while the power required rises to eight times that at half speed.

These facts should be clearly borne in mind in the selection of a fan, and, so far as circumstances will permit, a large fan operating at moderate speed should be chosen, as a means of not only decreasing the power required but of also reducing the losses due to excessive friction in the ducts incident to the movement of air at higher pressure. For factory and mill work the fan may approach nearer to the minimum size, for higher air velocities are not only permissible but frequently desirable to force the air long distances, while the usual presence of an experienced engineer ensures more frequent attention where the fan is constantly operated at high speed. In the schoolhouse, the theatre, the church, and similar structures, where a much more complete system of air distribution is necessary and where only low velocity currents are permissible, the fan should be of the maximum size, capable of delivering the required volume of air at the least practicable speed.

To summarize, it is necessary in the selection of a fan to first determine its required capacity, to then decide upon the type to be adopted, and to finally select the size best adapted to the given requirements as largely influenced by the maximum speed allowable. Such selection cannot be alone based upon published tables of fan capacities, for even with the type of fan clearly defined there is opportunity for disastrous mistakes in deciding upon speed and in making the allowances that are necessary for the loss in volume moved, due to the resistances encountered in passing through the heater and through the distributing ducts. The tendency, from a commercial standpoint, is strongly toward the selection of too small a fan and to this fact is due the failure of many of the earlier plants installed under the specifications of those who possessed but limited experience in these matters. Therefore the selection of the type of fan and the determination of its size should be left to parties fully qualified to decide upon this important factor in the heating and ventilating system.

GENERAL ARRANGEMENT OF THE STURTEVANT SYSTEM. As already indicated, the Sturtevant System of Heating and Ventilation comprehends only that method by which ventilation is secured under plenum conditions, that is, where the air is forced into, rather than exhausted from, the building, and comprises in its entirety a steam heater or heaters, a fan driven by some type of

motor and a system of ducts and flues through which the air is forced to the various apartments of the building. The size and arrangement of these ducts and flues, as well as the location of the apparatus, is directly dependent upon the construction and use of the building.

Although several States now legally require adequate ventilation in factory buildings, yet it must be admitted that in the introduction of the Sturtevant System the owner's first motive is usually mercenary rather than humanitarian. But the Sturtevant System fortunately possesses this particular feature, considered solely as a heating system, namely, that in order to heat successfully it is necessary to supply a volume of air sufficient at the same time to thoroughly ventilate any ordinary factory structure where the processes are no more than ordinarily objectionable.

The introduction of the Sturtevant System is, therefore, divided between two great classes of buildings.

First, where heating is pre-eminent and ventilation is merely incidental, and—

Second, where the system of ventilation is of primary importance, and heating is necessarily combined with it for successful operation rather than introduced as an independent system.

To the first class belong almost exclusively all manufacturing buildings, storehouses, drying-rooms, exposition buildings, and some offices and stores.

In the second class are those buildings in which specially objectionable processes are carried on, hospitals and asylums, all halls of audience (including theatres, churches and schools), and stores and offices not included in the first class.

The enterprising manufacturer is quick to appreciate his financial interest in the provision and maintenance of an atmosphere in his factory that exhilarates rather than wearies his employees; for a direct monetary return can be shown in the improvement in quantity and quality of work resulting from the introduction of this system with pure air and a comfortable temperature.

Considerations of economy and the before-mentioned idea of the owner, that *heating* is the pre-eminent feature desired in the application of the system in a factory, have much to do with the location of the apparatus. To secure economy in heating where improved ventilation does not enter into the question, the apparatus is frequently arranged so as to take its air supply entirely from within doors, thereby simply turning the air over and over within the building. There is, however, an incidental leakage resulting in a degree of ventilation considerably in excess of that occurring with any system of direct steam heating. To this end, in a one-story structure the apparatus should be placed as near the centre as possible, so that the air may be drawn back to it from all sides.

# VENTILATION AND HEATING

Dependent upon the character and construction of the building, one of two general methods of distribution may be adopted. The first and most common is by a more or less extended system of metal ducts or pipes, almost universally constructed of galvanized iron on account of its durability. Such a system is the only one practicable in wooden structures. In brick buildings, particularly those of two or more stories, brick ducts and brick vertical flues are the most convenient, and, as usually applied, do not encroach upon valuable interior floor space.

The one-story structure with brick, wood or metal sides, with sloping roof surmounted by skylight or monitor, forms to-day the model for the foundry and the machine, boiler or blacksmith shop, while its use is rapidly extending to other trades. In such a building some arrangement of galvanized iron distributing pipes is compulsory, for the brick duct and flue become too expensive proportionally to the cubic contents to be heated.

In comparatively narrow wooden structures, where it is a question of galvanized iron pipe or nothing, the main distributing pipe extends lengthwise of the basement and there connects with risers carried up alongside of the supporting columns of the building, from which the air is discharged towards the walls through properly located outlets about 8 or 9 feet above each floor.

The ideal installation of the Sturtevant System is in the three or four-story brick factory of the type of the ordinary cotton mill, where the heated air is conducted from the apparatus through a duct in the basement to the bases of special pilaster flues located upon the outside at regular intervals along one side of the building. The horizontal duct constructed of brick, usually extends along the interior of the basement wall, and is provided with either a flat or arched top of approved and air-tight material, or is made quadrant in form, thereby securing for a given expenditure of material the maximum area for the passage of air. At distances varying from 40 to 75 feet, the piers between the windows are carried out and form the pilaster flues which receive the heated air from the duct and discharge it above the head line on each floor.

Most prominent among the buildings in which the ventilation may be considered of primary importance are those in which persons remain for several hours closely seated and practically inactive, as is the case with an audience in a church or a theatre and with the pupils in a schoolroom. Here the *per capita* air space in the room is at its minimum. In the best modern schoolroom there is usually an allowance of 250 cubic feet of space per occupant; but in many theatres and halls this figure is reduced as low as 75 to 100 cubic feet to each person.

In the ordinary schoolroom a supply of 30 cubic feet per head per minute would necessitate changing the entire volume of the room once in about eight

minutes, while in a hall with only 75 cubic feet of space for each member of the audience such a supply of air would require a complete change once in every two and one half minutes. It is difficult, without extreme care, to so introduce such an excessively large volume of air under these latter conditions without creating objectionable draughts about the occupants.

In this climate a perfect system of heating and ventilation applied to a building of the aforementioned class, should,—

First, maintain within each room a mean temperature of 70° F., irrespective of changes in external temperature, with a total variation of not over 2° or 3° above or below this mean at a given level in any occupied portion of the room.

Second, supply to the room, under all conditions of indoor and outdoor atmosphere, a constant predetermined volume of air, and deliver it without creating objectionable draughts and in such a manner as to be thoroughly and efficiently distributed throughout the apartment.

This second requirement may even be so exacting as to demand a constant indoor temperature, with variable supply of air proportioned to the varying number of persons occupying the room. Assuredly, with no arrangment or device can the air supply be more readily proportioned to the requirements than with the Sturtevant System. Doubtless at the present time more attention is being given to improvement in schoolhouse ventilation than to that of any other class of structures; and fortunately the ordinary schoolhouse, with its brick partition walls, presents a most excellent opportunity for the economical placing of the necessary flues, for they may be grouped along the interior walls and provided with inlet openings about 8 feet above the floor and vent openings at floor level.

The hall and the church are in reality but enlarged schoolrooms as regards their treatment by the blower system. The same vital requirement holds: that the temperature must be maintained independent of volume of air admitted, while the difficulty of satisfactorily admitting the required air supply is increased by the closer seating of the audience.

The theatre presents far more complication than the hall; its three parts — stage, auditorium and lobbies — may at one moment be essentially one and the next be rendered practically independent. The auditorium is usually thoroughly protected by the lobbies or the walls of adjacent buildings, so that the heat loss is reduced to a minimum, and during a performance it becomes a question of cooling rather than of warming the occupants.

In some cases the air has been supplied entirely through perforated ceilings, whence it passes down over the persons of the audience and escapes through a multitude of openings in floor and risers. This unnatural movement of the air

against its own impulse must be facilitated by exhaust fans connected to the area beneath the floor in addition to the plenum fans for forcing in the fresh air.

The rapid improvement in theatre ventilation certainly indicates that the enterprising manager sees therein another inducement to the theatre-going public to patronize his individual house in preference to one where the air is foul and oppressive, although the dramatic attraction may be equally good.

The requirement of large air volume *per capita* in hospitals and asylums, particularly in contagious wards, necessitates positive and ample means which can only be satisfactorily met by the fan, standing as it does, capable, according to its size, of supplying any amount of air required. The store with its extended floor areas, and the office building with its multiplicity of small rooms, call for arrangements peculiarly their own. In fact, the ready adaptability of the Sturtevant System to diverse conditions forms one of its salient features. Many illustrations of its application are presented in succeeding pages; the preceding brief outline being here given only to indicate the general scheme of application.

DOUBLE DUCT SYSTEM. The varying exposures of the rooms of a school or other building similarly occupied, require that more heat shall be supplied to some than to others. The sunlit, southerly room, perhaps still more favored by being over the boiler, may be kept perfectly comfortable with a supply of heat that perchance will barely maintain a temperature of 50° to 60° F. in a room on the opposite side of the building, exposed to high winds and shut off from the warmth of the sunshine. With a constant and equal volume of air supply to each room, it is evident that its temperature must be directly proportional to the cooling influences within and around the room, and that no building of this character is properly heated and ventilated where the temperature cannot be varied without affecting the air supply.

To this end, air of a given temperature may be conducted to the base of each flue and there tempered to a degree suitable to the requirements of the room supplied. Two methods appear:

The older arrangement consists in heating the air by means of a primary coil, at or near the fan, to about 60° F., or to the minimum temperature required within the building. From the coil it passes to the bases of the various flues, and is there still further heated by secondary or supplementary heaters, one or more to each room. Under certain conditions the distribution ducts may be omitted, and the entire sub-basement made to serve as a large plenum chamber containing air under slight pressure heated to about 60° F. by the main coil.

With the second and more recent method a single heater is employed, the supplementaries are discarded, and all of the air is heated to the maximum required to maintain the desired temperature in the most exposed rooms, while variety in temperature of air supplied to the other rooms is secured by mixing with the hot air a sufficient volume of cold air at the bases of the respective flues. This result may be best accomplished by designing a hot blast apparatus so that the air shall be forced rather than drawn through the heater, and by providing a by-pass through which it may be discharged without passing across the heated pipes.

This discharge for the unheated air is usually made above and separate from the heater pipes. Extending from the apparatus is a double system of ducts, almost universally constructed of galvanized iron and suspended from the ceiling. At the base of each flue is placed a mixing damper which is controlled by chain from the room above, and so designed as to admit either a full volume of hot air, a full volume of cold air, or to mix them in any desired proportion without affecting the resulting total volume delivered to the room. Where perfect and continuous regulation, independent of the teacher, is desired, the damper should be operated by a thermostat in the room with which the flue connects.

The *hot and cold system*, as this double duct is familarly known, accomplishes at less expense, with greater rapidity and equal certainty, the results obtained by the more complicated method previously described, and is being extensively introduced in the modern schoolhouse wherever the blower system is applied. As ordinarily installed, the hot air and the cold air connection to each mixing damper are of equal area so that whether the air be hot or cold or a mixture of the two, its volume will remain constant.

An accurate calculation of the resulting temperature when two known volumes of air of given temperatures are mixed must take into consideration the temperature, weight and humidity of these volumes; but for rough estimating and for purposes of comparison the difference in weights and humidity may be disregarded. It then becomes merely a question of averaging of the simplest kind. Thus, for instance, if of a stated resulting volume, 4 parts were introduced at a temperature of 30° and 6 parts at a temperature of 120°, the calculation would be merely $\frac{(4 \times 30) + (6 \times 120)}{10} = 84$.

In this manner the accompanying diagram (Fig. 5) has been laid out simply to illustrate the relative mixtures and resulting temperatures under a given set of conditions. As a fair average for schoolhouse work, 120° has been taken as the initial temperature of the hot air in its relation to various proportional mixtures

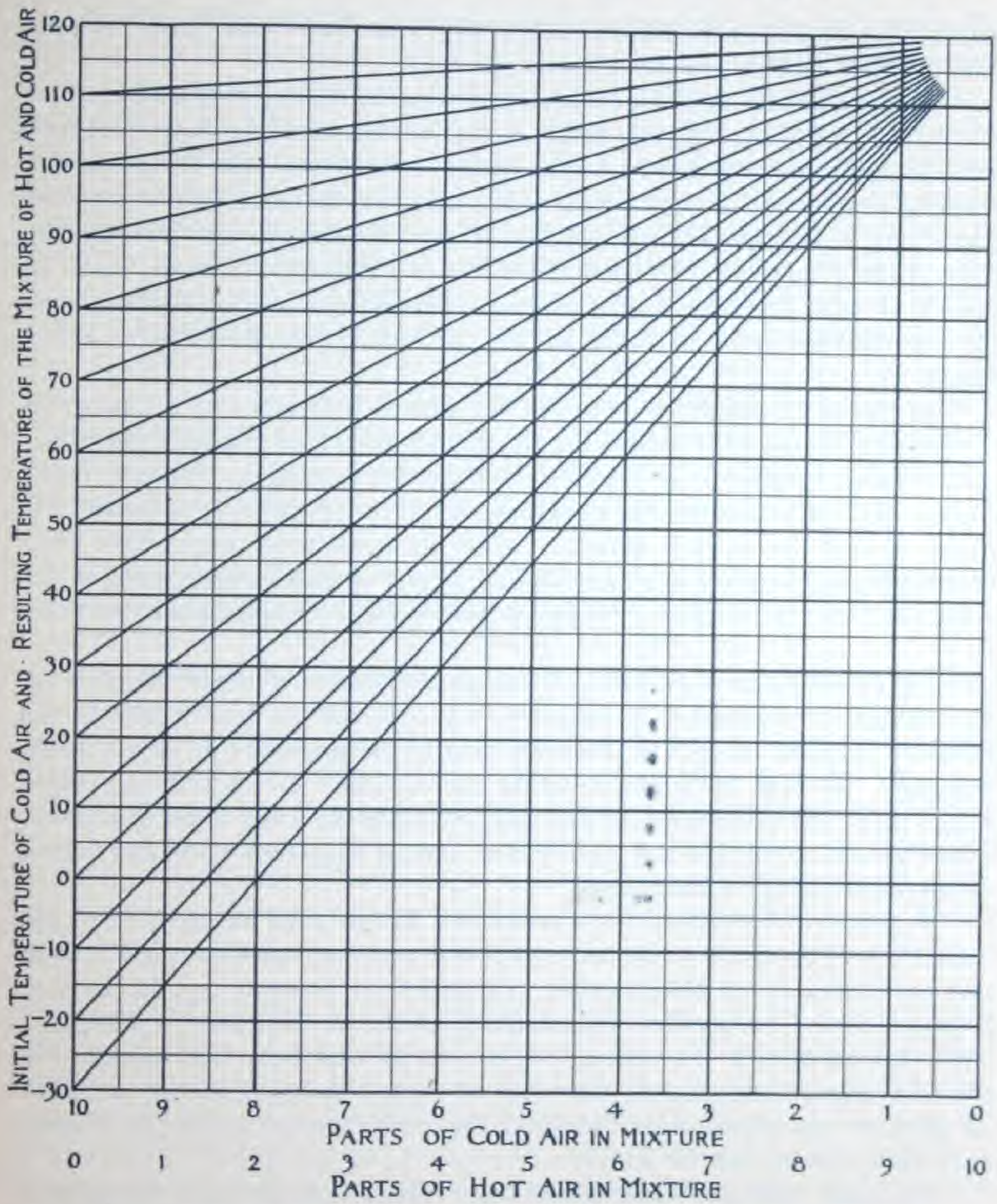



FIG. 5. RESULTING TEMPERATURES OF VARIOUS MIXTURES OF HOT AND COLD AIR.

with cold air at 30° up to 120°; of course the terms "hot" and "cold" become here distinctly relative; in fact, they always are.

The vertical lines upon the diagram represent the relative proportions of hot and cold air as indicated by the figures at the bottom, while the horizontal lines serve as measures both of the initial temperature of the cold air and of the resulting temperature of the mixture, which latter may be read from the diagonal line ending in the given initial temperature of the cold air. For instance, the temperature of a mixture of 3 parts of cold air of 20° temperature and 7 parts of hot air of 120° (the basis for the diagram), may be read at the intersection of the diagonal from point 20 on the left and the vertical from the point 30 and 7 below.

As previously stated, the correction for change in weight due to change in temperature has not been applied, but the diagram shows, nevertheless, the results of the given conditions in a manner sufficiently accurate to facilitate ready comparison. Of course the cold air figures refer to the temperature of the air as it passes through the mixing damper. What its temperature might have been before entering the apparatus must depend largely upon the arrangement of the system and the total amount of cold air passing through the apparatus at the time.

DISTRIBUTION OF AIR. Thorough distribution of the air supplied by any system of ventilation is necessary, not only for the best results in the matter of dilution, but also to absolutely prevent the possibility of objectionable draughts. In halls of audience, where the occupants are at rest, any slight inequality in the distribution is particularly noticeable; while in the workshop, where all are in motion and not in close contact with each other, less refined arrangements will give satisfaction.

Experiment has shown that a velocity of air less than nineteen inches per second is not perceptible to the senses, and that an air movement as high as three feet per second is not objectionable. Perception of draughts depends largely, however, on the temperature and humidity of the air in motion as compared with that normal in the room. It is evident, therefore, that special care should always be exercised, in order that no current having a velocity in excess of three feet per second, or one hundred and eighty feet per minute, be allowed to come in contact with the body.

The same method of distribution is not applicable in all cases. On general principles, it may be asserted that, wherever the air is cooled in its progress or passage through a room, that it will best serve its purpose as a means of heating and ventilating if it be admitted to the room at a point most distant from the

outer walls. This point of discharge should be at least eight feet above the floor, and the air movement should be directly toward the outside walls. Such an arrangement is very easy of introduction in a building having interior partition walls, as an office, a dwelling, or a school building, for the flue may be constructed within or against these walls. Thus located, the air discharged from the outlet passes in a constantly spreading volume above head level toward the exposed walls, where, becoming slightly cooled, it slowly settles to the floor. To complete the circuit and fulfil the design, the ventilating register should be in the same inner wall as the supply opening, but close to the floor. There is thus induced toward this outlet a return flow of the air in a well-distributed mass. The currents are, in reality, stratified, the lower one serving to take up the emanations from the lungs of the occupants as its sweeps slowly across them directly towards the ventilating register. In factory heating no ventilating flues are provided, as there is always sufficient leakage of air around windows and through porous walls; but the air should, nevertheless, be introduced above head level.

In the case of theatres, and of most halls and churches, the large number of occupants serves, by the animal heat generated, to visibly increase the temperature of the air admitted. The conditions are, therefore, exactly the reverse of those where the air is cooled in transit, and the best results are obtained by causing the air movement to be directly upward, or, as in the case of some recent installations, directly downward, with the air supply through the ceiling. Minute sub-division of the supply is an absolute necessity when it is admitted through the floor, and with either the upward or the downward method the design is to secure individual ventilation, so far as may be practically possible. The details of construction necessary to secure the proper air movement for these various classes of buildings will be made evident in the illustrations which follow.

ARRANGEMENT AND CONSTRUCTION OF DUCTS AND FLUES. The arrangement of the system of ducts and flues within a building must, of necessity, be dependent upon the method of distribution adopted, which in turn will be largely influenced by the construction of the building. If of brick, the flues may be most readily and economically built in the walls as the building is erected. Such a procedure, however, presupposes the selection of the system before the building plans are completed. As natural and necessary as this may seem, it is lamentably true that such decision is very frequently delayed until the building is under way.

Under such circumstances, it is usually necessary to provide for the distribution through metal ducts, whose position is seldom what it should be, owing to the exigencies of architectural features. In fact, the day has not yet arrived when hygienic demands always take precedence over architectural symmetry and beauty. Not that harmonious architectural composition cannot be preserved when proper provision is made for heating and ventilating flues, but that the work of the architect is too frequently schemed and the drawings completed without adequate consideration of the ventilating system to be adopted. It is surprising how successfully flues can be introduced without marring the general effect, for it is a simple matter to work them in as false columns, pilasters, beams, or cornices, or to introduce perforated ceilings, without attracting attention.

In an old building metal ducts and flues are almost a necessity, the material employed generally being galvanized iron. When ducts are to be placed underground, they should be of brick for the larger sizes, while glazed tile pipe will serve for smaller ones. Flues — which in matters of ventilation are generally classed as vertical air passages in distinction from ducts, by which name are designated the horizontal conduits — should always be smoothly finished inside, and where the expense will permit, it is wise to line their interiors with sheet metal, either tin or galvanized iron, or with special terra-cotta flue linings which are made for the purpose.

So far as possible the flues should be banked together for economy in construction, but independent flues should be provided for individual rooms, to insure equality of distribution, except where they are large, as in the mill and factory. With this arrangement a heating flue for the first floor may readily be stopped off above the outlet opening and employed as a ventilating flue from the floor above. It is best to carry all ventilating flues separately, above the roof, although very good results may be obtained under the plenum system, where they simply discharge into the attic, from which escape is provided through a cupola or louvered windows. If the complicated nature of the building demands that an exhaust fan be used, it should be directly connected with the flues. An exhaust fan simply drawing from the attic space and discharging out of doors will prove very inefficient, owing to the ease with which a portion of its supply will find its way, by leakage, through the roof rather than be drawn from the rooms below. As a result, the fan performs only a part of the definite duty assigned to it, and the amount of air which should be withdrawn from the rooms is so seriously reduced as to decidedly impair the ventilation.

# VENTILATION AND HEATING

Too much care cannot be taken in the design and construction of a system of ducts and flues. Owing to the small scale upon which the general scheme is, in most cases, necessarily shown, and the general lack of detail drawings for individual features, the galvanized iron worker and the mason are usually left, to a considerable extent, to their own devices to accomplish the desired results. This may be well enough in the case of men experienced in this line of work, as is particularly the case with those employed continuously on galvanized iron work by large and established heating and ventilating concerns. But the local tinsmith and the ordinary mason are very apt, from inexperience, to fail to properly construct such work.

FIG. 6.

The disastrous effect of sudden turns must be thoroughly realized, and wherever a change in direction is necessary, it must be made with as generous a curve as possible. In galvanized iron piping, "stove-pipe elbows," so-called, should always be avoided, and turns of direction of 90° constructed, in the case of round pipe, with at least five pieces, and with the radius of curvature of the inner side of the elbow at least equal to the diameter of the pipe. Such an elbow is represented in Fig. 6. This proportion of radius to size holds whether the pipe be round or rectangular.

FIG. 7.

A great source of unnecessary friction and undue resistance often results from the butting of a branch pipe squarely into the side of the main pipe. Instead, the branch nipple should be cut into and securely attached to the pipe at an angle of 45°, and the remainder of the change in direction made by using a half elbow, all as clearly shown in Fig. 7. It is to be noted that the main pipe is reduced in area after the branch is taken out, and that this reduction, or taper, is very gradual. It is the usual practice in well made piping to make this taper equal in width to a sheet of galvanized iron, which, with the usual thirty-inch-wide sheet, will give a net length of twenty-eight inches when the pipe is put up. The same method should be employed with regard to reductions in the size of all forms of rectangular ducts.

Wherever a branching or division of the main pipe is to be made, and even in cases where a relatively large branch is to be taken from the side of the main pipe, the piece should be so constructed as to proportionally divide the air currents; that is, in such a way that the air volume is practically split by the opposing acute angle, and easily, but positively, compelled to change its direction of movement. Such a branch, or divided outlet, is illustrated in Fig. 8, as applied to a round pipe. Rectangular pipe should be treated upon the same general principle, which is here much more easily applied. Fig. 9 indicates the form in which it should be constructed where one portion is to continue in the same direction and the other turn to a direction at right angles. In reality, the reduction in area beyond the branch is made in the process of taking out the branch, and by its arrangement serves to catch and deflect the requisite amount of air. Pipe of this form and construction is largely employed in public building and schoolhouse work, for the purpose of distributing the heated air from the apparatus to the bases of the various vertical flues. When thus employed, it is usually suspended close beneath the basement ceiling, and made of such depth as to allow ample head room, thus forming as a rule a comparatively flat pipe.

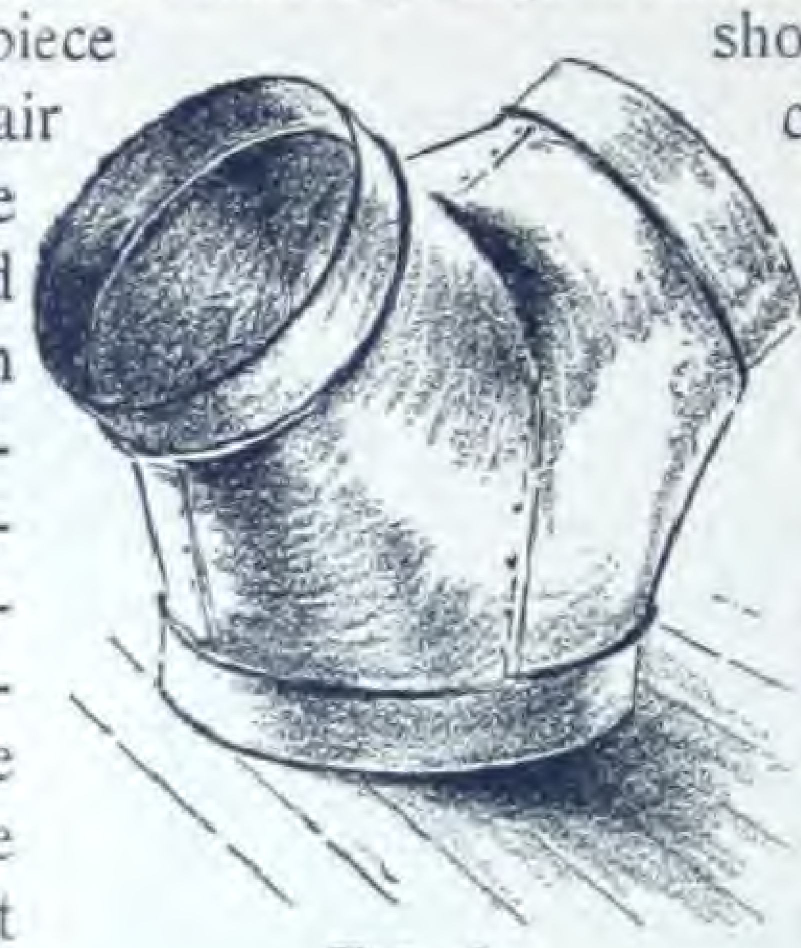


FIG. 8.

With all due regard in the design to the unequal resistances of ducts and flues of different areas and lengths, it is always best to additionally provide, in the main supply system, the means of primary permanent equalization of air volumes to the various flues. To this end, all such branches as that shown in Fig. 9 should be provided with light and short flap dampers, easily adjusted from outside the pipes and permanently held in place by set-screwing the rods when turned to the proper position. This damper is very clearly indicated in the cut. In small pipes, a mere extension of flexible sheet iron from the dividing angle will serve the purpose, and may be adjusted through a handhole in the pipe, which should be provided with a slide.

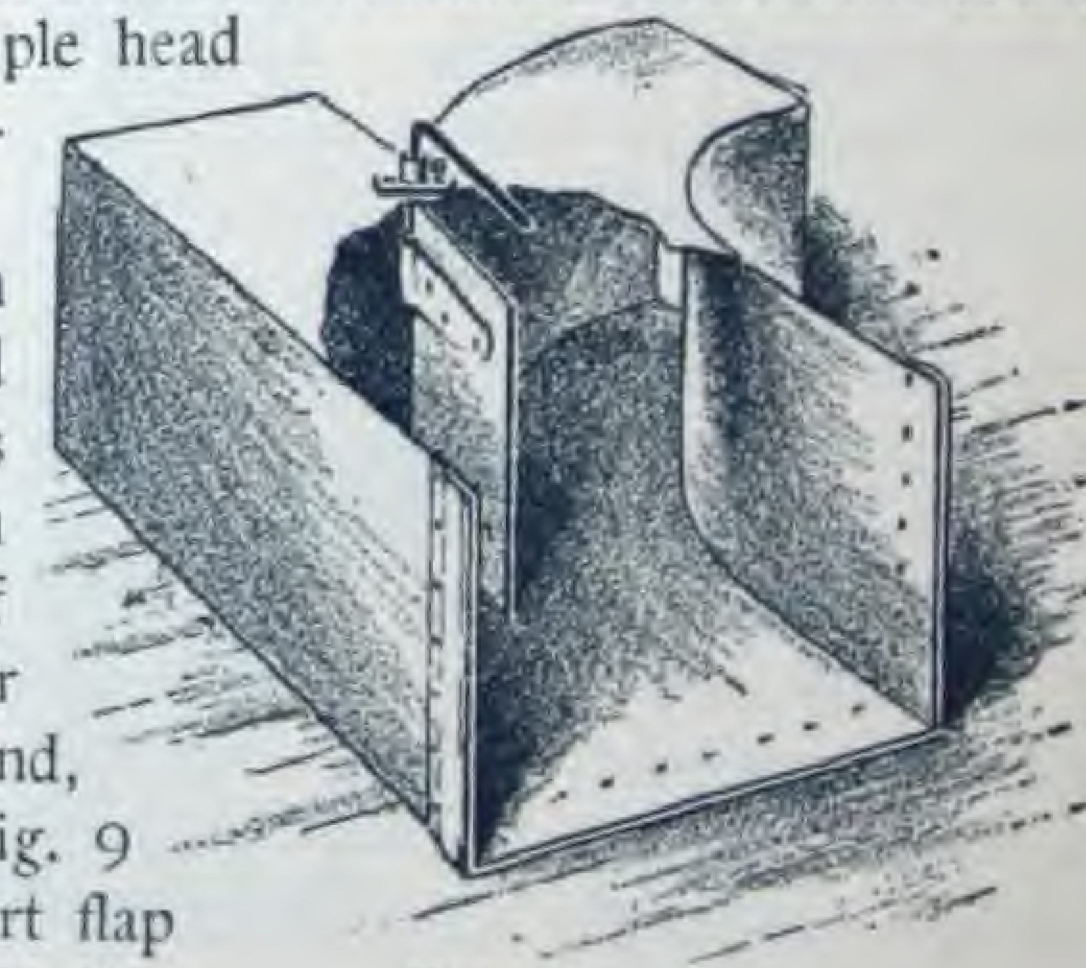


FIG. 9.

The same principles hold in the construction of brick ducts and the introduction of tile pipes. The difficulty in brickwork generally lies in the unwillingness of the mason to introduce curves, because of the extra care required in laying them. But misproportioned brick ducts, and the lack of proper adherence to drawings, has resulted in serious trouble in many cases. A typical construction is presented in Fig. 10, and it is to be noted how easily the air is deflected into the side branch. The tops of such ducts may be arched, as shown, or may be covered with properly spaced T irons, between which bricks are laid and thoroughly bedded in mortar.

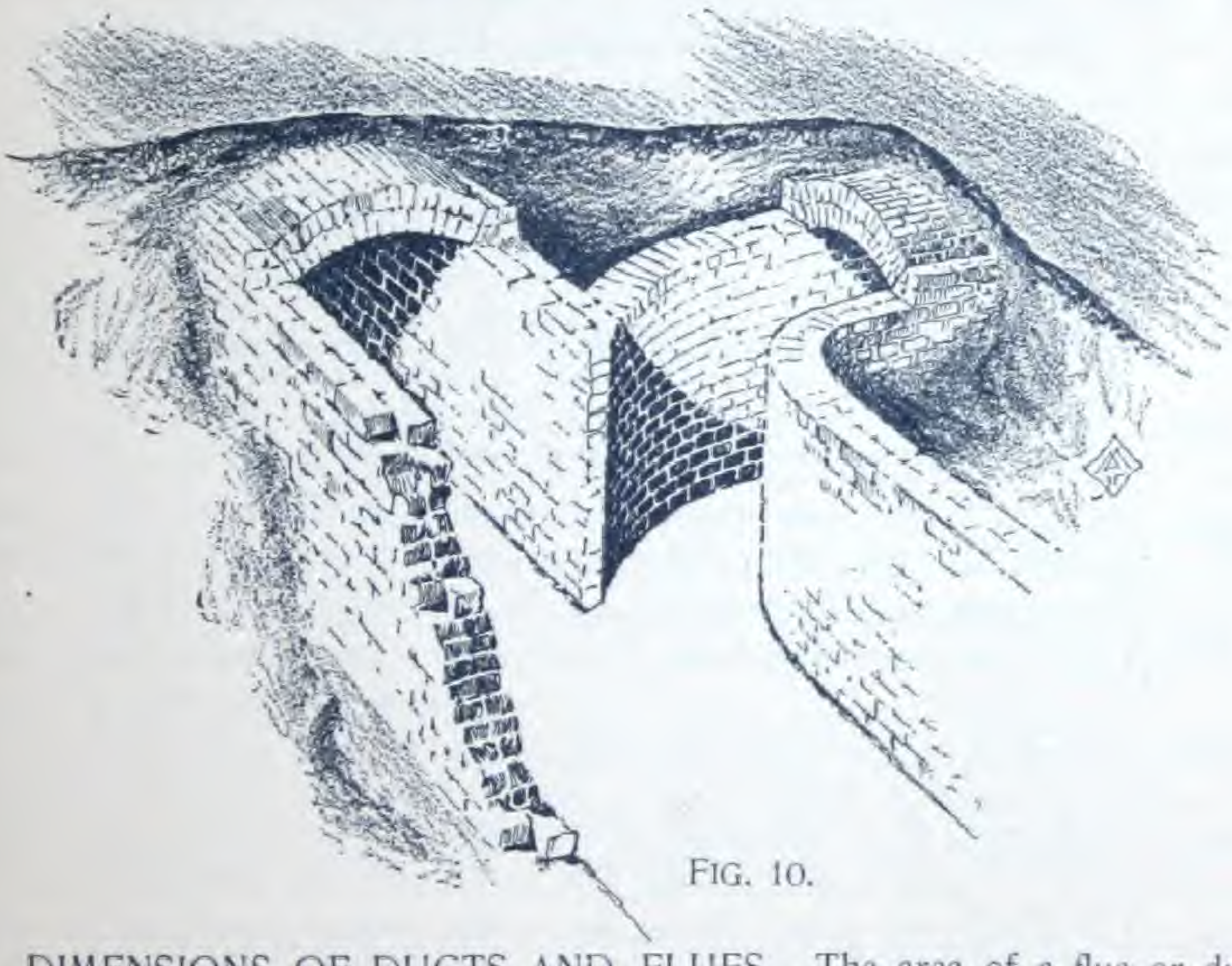


FIG. 10.

DIMENSIONS OF DUCTS AND FLUES. The area of a flue or duct is obviously determined by the volume of air destined to pass through it and the permissible or desirable rate of flow. From a consideration of the fact that the losses due to friction of air in its movement through pipes increase as the square of the velocity, so that doubling the velocity increases the friction fourfold, it would at first appear that the ultimate object in any design should be to move the air at the lowest possible velocity, but the accomplishment of such an object obviously demands ducts of vast size. It is plainly evident, however,

that the interest account on the increased cost of such ducts may readily exceed the saving in power attained by reducing the rate of air movement. It is further true that, in any successful system of ventilation, it is necessary, in order to secure positive circulation, that the velocity and pressure of the air should not be allowed to fall below a prescribed minimum. But, most important, as rendering the general question of velocities of still less importance from an economical

## TABLE No. 6.

## Of the Losses in Pressure and Horse Power Due to Friction of Air Passing Through Pipes.

| Diameter of Pipe in Inches. | Loss of Pressure and Horse Power. | Velocity of Air in Feet per Minute. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 | 2400 | 2600 |
| 12 | Loss of Pressure in ozs. per sq. in. | .092 | .133 | .181 | .237 | .300 | .370 | .448 | .533 | .626 |
| | Horse Power lost in Friction. | .0198 | .0343 | .0544 | .0812 | .1156 | .1586 | .2111 | .2741 | .3485 |
| 18 | Loss of Pressure in ozs. per sq. in. | .062 | .089 | .121 | .158 | .200 | .247 | .299 | .356 | .417 |
| | Horse Power lost in Friction. | .0297 | .0512 | .0816 | .1218 | .1735 | .2380 | .3167 | .4112 | .5228 |
| 24 | Loss of Pressure in ozs. per sq. in. | .046 | .067 | .091 | .119 | .150 | .185 | .224 | .267 | .313 |
| | Horse Power lost in Friction. | .0397 | .0685 | 1088 | .1624 | .2313 | .3173 | .4223 | .5483 | .6971 |
| 30 | Loss of Pressure in ozs. per sq. in. | .037 | .053 | .073 | .095 | .120 | .148 | .179 | .213 | .250 |
| | Horse Power lost in Friction. | .0496 | .0857 | .1360 | .2031 | .2891 | 3966 | .5279 | .6855 | 8714 |
| 36 | Loss of Pressure in ozs. per sq. in. | .031 | .044 | .060 | .079 | .100 | .123 | .149 | .178 | .209 |
| | Horse Power lost in Friction. | .0595 | .1024 | .1632 | .2437 | .3469 | .4759 | .6334 | .8224 | 1.0456 |
| 44 | Loss of Pressure in ozs. per sq. in. | .025 | .036 | .049 | .069 | .082 | .101 | .122 | .145 | .171 |
| | Horse Power lost in Friction. | .0727 | .1256 | .1995 | .2938 | .4240 | .5817 | .7742 | 1.0051 | 1.2779 |
| 52 | Loss of Pressure in ozs. per sq. in. | .021 | .031 | .042 | .055 | .069 | .085 | .103 | .123 | .144 |
| | Horse Power lost in Friction. | .0859 | .1485 | .2360 | .3520 | .5011 | .6874 | .9150 | 1.1879 | 1.5103 |
| 60 | Loss of Pressure in ozs. per sq. in. | .019 | .027 | .036 | .047 | .060 | .074 | .090 | 107 | 1.25 |
| | Horse Power lost in Friction. | .0991 | .1713 | .2721 | .4061 | .5782 | .7932 | 1.1607 | 1.3706 | 1 7427 |

standpoint, is the fact of the almost universal employment of the steam engine for driving the fan in connection with the Blower System. The common practice of utilizing the exhaust steam in the heater reduces the actual cost of moving the air to practically nothing. Table No. 6 presents, in limited form, the rela-

tion existing between size of pipe, velocity of air, and losses in pressure and horse-power. These losses are proportional to the area of the pipe surface with which the air comes in contact; therefore, a round pipe offers the least resistance per cubic foot of air moved, a flat rectangular pipe being most inefficient.

In almost all public building work, the definite object of the system is to deliver the air to the rooms at such velocity as to secure its movement to the desired points, but without objectionable draughts, or the humming of the air as it passes through the registers, which latter is very likely to occur at velocities of about 1,000 feet per minute. To this end, the average velocity through the net area of the screen or register should not, under ordinary conditions, exceed 500 feet per minute. For average-sized schoolrooms a velocity as low as 400 feet is more desirable, while in small rooms, as in dwellings, this may well be reduced to 300 feet per minute. It is always best to keep the velocity through floor registers, at least, as low as this, and preferably lower still. To secure a fairly equable discharge through the full area of a screen or register supplied from a vertical flue, the velocity in this flue should not exceed that through the outlet by more than fifty per cent. Ordinarily, flue velocities in such buildings range from 500 to 800 feet per minute. The rate of flow through the connections to the bases of the flues should in turn be higher than that through the flues themselves, while the velocity in the main horizontal distributing ducts would be even higher. In fact, in buildings of this class the plan should be to gradually reduce velocities from the point of leaving the fan to the point of discharge to the rooms. Careful investigation has shown that, everything considered, the velocity in the main horizontal ducts from the fan should not be below 1,500 feet, and preferably 2,000 feet, per minute.

In the case of a manufactory, or wherever rooms are of excessive size, the treatment should be radically different. Here, a high velocity is necessary to assure the passage of the air to the most distant points. It is not at all infrequent in such buildings to force it 100 to 200 feet from the outlet. The conditions which will permit of such air movement will be made more evident in succeeding illustrations of the system as applied to manufacturing establishments. A high velocity at the discharge outlet is evidently necessary to force the air for such a distance through the open room. Very slight increase is, therefore, made over the area of the fan outlet. As the fan in such a building is usually operated at its maximum speed, — the air leaving its outlet at a velocity of about 3,500 feet per minute,— even a fairly generous increase in areas will maintain its discharge through the flue outlets at velocities of from 2,000 to 3,000 feet per minute. Of course, with such high velocities, the frictional losses are increased;

but, the fan being operated at higher speed, the proportional losses are no excessive, while the rapidity of movement reduces the time during which the moving air within the conduits may part with its heat to the surrounding atmosphere.

According to the character of the building, two methods appear for figuring the ducts and flues. In a manufactory — after determining the fan capacity required and the relative volumes of air necessary for the various rooms, as based upon their cubic contents, their desired temperature and their exposure — there may be calculated a constant number representing the square inches of outlet of the fan per 1,000 cubic feet of space as reduced to a standard of heating to the basis temperature. In a compact system, with a small number of outlets, it is a very common custom to make the aggregate area of these outlets about twenty-five per cent. in excess of the area of the fan outlet. From this may be determined the square inches of pipe outlet per 1,000 cubic feet of space, and the areas proportioned to the requirements. This excess of area of outlets over the fan outlet demands that the main pipe shall not be reduced exactly in proportion to the outlets taken from it as it extends from the fan, but at such a less ratio that at the end of the system the main pipe shall be practically equal to the area of the last outlet or group of outlets.

In a school or similar building, where the hot and cold duct system is to be introduced, and the air distribution is to be made respectively proportional to the number of occupants of the individual rooms, the process is practically the reverse. The register or screen area, dependent upon the selected velocity through the same, will be determined by dividing the total volume per minute by the rate of flow per minute. The flue area will, in turn, be determined in a similar manner, and thus the distributing system will be worked out backward, so to speak, through lines of increasing velocities, to the fan itself. It is very desirable, however, to maintain through the connection at the base of each flue a velocity considerably higher than that in the flue, in order to counteract all tendency to unequal flow, and to render any adjustment of the primary distributing dampers more efficient.

To facilitate calculation by either method of figuring the distributing system, Tables Nos. 7 and 8 have been prepared, the one showing the area in square inches of flue or register required for any given air change, and the other the flue or register area necessary for the passage of any given volume at a stated velocity. Values for volumes below 100 or above 1,000 cubic feet may be readily determined from the latter table by reading for the multiple of the given volume, and then pointing off the requisite number of places. Thus, if a

## TABLE No. 7.

### NUMBER OF SQUARE INCHES OF FLUE AREA REQUIRED PER 1,000 CUBIC FEET OF CONTENTS FOR GIVEN VELOCITY AND AIR CHANGE.

| No. Minutes to Change Air. | VELOCITY OF AIR IN FLUE IN FEET PER MINUTE. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 |
| 4 | 120. | 90. | 72. | 60. | 51.6 | 45. | 40. | 36. | 32.2 | 30. | 27.6 | 25.6 | 21.4 |
| 5 | 96. | 72.2 | 57.6 | 48. | 41.1 | 36.1 | 32. | 28.8 | 26.2 | 24. | 22.2 | 20.5 | 19.2 |
| 6 | 80. | 60. | 48. | 40. | 34.3 | 30. | 26.6 | 24. | 21.8 | 20. | 18.5 | 17.1 | 16. |
| 7 | 68.6 | 51.4 | 41.1 | 34.3 | 29.4 | 25.7 | 22.9 | 20.6 | 18.7 | 17.2 | 15.7 | 14.7 | 13.7 |
| 8 | 60. | 45. | 36. | 30. | 25.8 | 22.5 | 20. | 18. | 16.1 | 15. | 13.8 | 12.8 | 12. |
| 9 | 53.3 | 40. | 32. | 26.6 | 22.9 | 20. | 17.8 | 16. | 14.5 | 13.3 | 12.3 | 11.4 | 10.7 |
| 10 | 48. | 36. | 28.8 | 24. | 20.6 | 18. | 16. | 14.4 | 13.1 | 12. | 11.1 | 10.3 | 9.6 |
| 11 | 43 6 | 32.2 | 26.2 | 21.8 | 18 7 | 16.1 | 14.5 | 13.1 | 11.9 | 10.9 | 10.1 | 9.5 | 8.7 |
| 12 | 40. | 30. | 24. | 20. | 17.2 | 15. | 13.3 | 12. | 10.9 | 10. | 9.2 | 8.6 | 8. |
| 13 | 36.9 | 27.7 | 22.2 | 18.5 | 15.7 | 13.8 | 12.3 | 11.1 | 10.1 | 9.2 | 8.5 | 7.9 | 7.4 |
| 14 | 34.3 | 25.7 | 20.6 | 17.2 | 14.7 | 12.8 | 11.4 | 10.3 | 9.5 | 8.6 | 7.9 | 7.4 | 6.9 |
| 15 | 32. | 24. | 19.2 | 16. | 13.7 | 12. | 10.7 | 9.6 | 8.7 | 8. | 7.4 | 6.9 | 6.4 |
| 16 | 30. | 22.5 | 18. | 15. | 12.9 | 11.2 | 10. | 9. | 8.2 | 7.5 | 6.9 | 6.4 | 6. |
| 17 | 28.2 | 21.2 | 16.9 | 14.1 | 12.1 | 10.6 | 9.4 | 8.5 | 7.7 | 7. | 6.5 | 6.1 | 5.6 |
| 18 | 26.6 | 20. | 16. | 13.3 | 11.5 | 10. | 8.9 | 8. | 7.3 | 6 6 | 6.2 | 5.7 | 5.3 |
| 19 | 25.3 | 18.9 | 15.2 | 12.6 | 10.8 | 9.5 | 8.4 | 7 6 | 6 9 | 6.3 | 5.8 | 5.4 | 5.1 |
| 20 | 24. | 18. | 14.4 | 12. | 10.3 | 9. | 8. | 7.2 | 6.5 | 6. | 5.5 | 5.1 | 4.8 |

volume of 8,750 cubic feet of air is required to pass through a flue at a velocity of 900 feet per minute, the cross sectional area of that flue must be 1,400 square inches. The greatest difficulty is experienced in laying out a system for very small rooms, as the areas required become relatively minute and impracticable. Under such conditions, it is wise to calculate for lower velocities than usual, so as to make the ducts and flues of manageable size. As a rule, a pipe less than 5 inches in diameter, or a flue less than 8 x 8 inches, should be avoided.

Table No. 9, Of the Areas of Circles and of the Sides of Squares of the Same Area, will be found to be of service in all such calculations.

## TABLE No. 8.

### FLUE AREA REQUIRED FOR GIVEN VOLUME AND VELOCITY.

| Volume in Cubic Feet per Minute. | VELOCITY IN FEET PER MINUTE. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 |
| 100 | **48** | **36** | **29** | **24** | **21** | **18** | **16** | **14** | **13** | **12** | **11** | **10** | **9.6** | **9.** |
| 125 | 60 | 45 | 36 | 30 | 26 | 23 | 20 | 18 | 16 | 15 | 14 | 13 | 12. | 11.3 |
| 150 | 72 | 54 | 43 | 36 | 31 | 27 | 24 | 22 | 20 | 18 | 16 | 15 | 14.4 | 13.5 |
| 175 | 84 | 63 | 50 | 42 | 36 | 32 | 28 | 25 | 23 | 21 | 19 | 18 | 16.8 | 15.8 |
| 200 | **96** | **72** | **58** | **48** | **41** | **36** | **32** | **29** | **26** | **24** | **22** | **21** | **19.2** | **18.** |
| 225 | 108 | 81 | 65 | 54 | 46 | 41 | 36 | 32 | 29 | 27 | 25 | 23 | 21.6 | 20.3 |
| 250 | 120 | 90 | 72 | 60 | 51 | 45 | 40 | 36 | 33 | 30 | 28 | 26 | 24. | 22.5 |
| 275 | 132 | 99 | 79 | 66 | 57 | 50 | 44 | 40 | 36 | 33 | 30 | 28 | 26.4 | 24.8 |
| 300 | **144** | **108** | **86** | **72** | **62** | **54** | **48** | **43** | **39** | **36** | **33** | **31** | **28.8** | **27.** |
| 325 | 156 | 117 | 94 | 78 | 67 | 59 | 52 | 47 | 43 | 39 | 36 | 33 | 31.2 | 29.3 |
| 350 | 168 | 126 | 101 | 84 | 72 | 63 | 56 | 50 | 46 | 42 | 39 | 36 | 33.6 | 31.5 |
| 375 | 180 | 135 | 108 | 90 | 77 | 68 | 60 | 54 | 49 | 45 | 42 | 39 | 36. | 33.8 |
| 400 | **192** | **144** | **115** | **96** | **82** | **72** | **64** | **58** | **52** | **48** | **44** | **41** | **38.4** | **36.** |
| 425 | 204 | 153 | 122 | 102 | 87 | 77 | 68 | 61 | 56 | 51 | 47 | 44 | 40.8 | 38.3 |
| 450 | 216 | 162 | 130 | 108 | 93 | 81 | 72 | 65 | 59 | 54 | 50 | 46 | 43.2 | 40.5 |
| 475 | 228 | 171 | 137 | 114 | 98 | 86 | 76 | 68 | 62 | 57 | 53 | 49 | 45.6 | 42.8 |
| 500 | **240** | **180** | **144** | **120** | **103** | **90** | **80** | **72** | **65** | **60** | **55** | **51** | **48.** | **45.** |
| 525 | 252 | 189 | 151 | 126 | 108 | 95 | 84 | 76 | 69 | 63 | 58 | 54 | 50.4 | 47.3 |
| 550 | 264 | 198 | 158 | 132 | 113 | 99 | 88 | 79 | 72 | 66 | 61 | 57 | 52.8 | 49.5 |
| 575 | 276 | 207 | 166 | 138 | 118 | 104 | 92 | 83 | 75 | 69 | 64 | 59 | 55.2 | 51.8 |
| 600 | **288** | **216** | **173** | **144** | **123** | **108** | **96** | **86** | **79** | **72** | **66** | **62** | **57.6** | **54.** |
| 625 | 300 | 225 | 180 | 150 | 129 | 113 | 100 | 90 | 82 | 75 | 69 | 64 | 60. | 56.3 |
| 650 | 312 | 234 | 187 | 156 | 134 | 117 | 104 | 94 | 85 | 78 | 72 | 67 | 62.4 | 58.5 |
| 675 | 324 | 243 | 194 | 162 | 139 | 122 | 108 | 97 | 88 | 81 | 75 | 69 | 64.8 | 60.8 |
| 700 | **336** | **252** | **202** | **168** | **144** | **126** | **112** | **101** | **92** | **84** | **78** | **72** | **67.2** | **63.** |
| 725 | 348 | 261 | 209 | 174 | 149 | 131 | 116 | 104 | 95 | 87 | 80 | 75 | 69.6 | 65.3 |
| 750 | 360 | 270 | 216 | 180 | 154 | 135 | 120 | 108 | 98 | 90 | 83 | 77 | 72. | 67.5 |
| 775 | 372 | 279 | 223 | 186 | 159 | 140 | 124 | 112 | 101 | 93 | 86 | 80 | 74.4 | 69.8 |
| 800 | **384** | **288** | **230** | **192** | **165** | **144** | **128** | **115** | **105** | **96** | **89** | **82** | **76.8** | **72.** |
| 825 | 396 | 297 | 238 | 198 | 170 | 149 | 132 | 119 | 108 | 99 | 91 | 85 | 79.2 | 74.3 |
| 850 | 408 | 306 | 245 | 204 | 175 | 153 | 136 | 122 | 111 | 102 | 94 | 87 | 81.6 | 76.5 |
| 875 | 420 | 315 | 252 | 210 | 180 | 158 | 140 | 126 | 115 | 105 | 97 | 90 | 84. | 78.8 |
| 900 | **432** | **324** | **259** | **216** | **185** | **162** | **144** | **130** | **118** | **108** | **100** | **93** | **86.4** | **81.** |
| 925 | 444 | 333 | 266 | 222 | 190 | 167 | 148 | 133 | 121 | 111 | 103 | 95 | 88.8 | 83.3 |
| 950 | 456 | 342 | 274 | 228 | 195 | 171 | 152 | 137 | 124 | 114 | 105 | 98 | 91.2 | 85.5 |
| 975 | 468 | 351 | 281 | 234 | 201 | 176 | 156 | 140 | 128 | 117 | 108 | 100 | 93.6 | 87.8 |
| 1000 | **480** | **360** | **288** | **240** | **206** | **180** | **160** | **144** | **131** | **120** | **111** | **103** | **96.** | **90.** |

## TABLE No. 8 (CONTINUED).

## FLUE AREA REQUIRED FOR GIVEN VOLUME AND VELOCITY.

| Volume in Cubic Feet per Minute. | VELOCITY IN FEET PER MINUTE | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 2400 | 2600 | 2700 | 2800 | 2900 | 3000 | 3100 |
| **100** | **8.5** | **8** | **7.6** | **7.2** | **6.9** | **6.6** | **6.3** | **6.** | **5.5** | **5.3** | **5.1** | **5.** | **4.8** | **4.6** |
| **125** | 10.6 | 10 | 9.5 | 9. | 8.6 | 8.2 | 7.5 | 7.5 | 6.9 | 6.7 | 6.4 | 6.2 | 6. | 5.8 |
| **150** | 12.7 | 12 | 11.4 | 10.8 | 10.3 | 9.8 | 9.4 | 9. | 8. | 8. | 7.7 | 7.5 | 7.2 | 7. |
| **175** | 14.8 | 14 | 13.3 | 12.6 | 12. | 11.5 | 11. | 10.5 | 9.7 | 9.3 | 9. | 8.7 | 8.4 | 8.1 |
| **200** | **16.9** | **16** | **15.2** | **14.4** | **13.7** | **13.1** | **12.5** | **12.** | **11.1** | **10.7** | **10.3** | **9.9** | **9.6** | **9.3** |
| **225** | 19.1 | 18 | 17.1 | 16.2 | 15.6 | 14.7 | 14.2 | 13.5 | 12.5 | 12. | 11.6 | 11.2 | 10.8 | 10.4 |
| **250** | 21.2 | 20 | 19. | 18. | 17.1 | 16.4 | 15.7 | 15. | 13.9 | 13.3 | 12.9 | 12.4 | 12 | 11.6 |
| **275** | 23.3 | 22 | 21.8 | 19.8 | 18.9 | 18 | 17.2 | 16.5 | 15.2 | 14.7 | 14.1 | 13.7 | 13.2 | 12.8 |
| **300** | **25.4** | **24** | **22.7** | **21.6** | **20.6** | **19.6** | **18.8** | **18.** | **16.6** | **16.** | **15.4** | **14.9** | **14.4** | **13.9** |
| **325** | 27.5 | 26 | 24.6 | 23.4 | 22.3 | 21.3 | 20.6 | 19.5 | 18. | 17.3 | 15.7 | 16.1 | 15.6 | 15.1 |
| **350** | 29.6 | 28 | 26.5 | 25.2 | 24. | 22.9 | 21.9 | 21. | 19.4 | 18.7 | 18. | 17.4 | 16.8 | 16.3 |
| **375** | 31.8 | 30 | 28.4 | 27 | 25.7 | 24.5 | 23.5 | 22.5 | 20.8 | 20. | 19.3 | 18.6 | 18. | 17.4 |
| **400** | **33.9** | **32** | **30.3** | **28.8** | **27.4** | **26.2** | **25** | **24** | **22.2** | **21.3** | **20.6** | **19.8** | **19.2** | **18.6** |
| **425** | 36 | 34 | 32.2 | 30.6 | 29.1 | 27.8 | 26.6 | 25.5 | 23.5 | 22.7 | 21.9 | 21.1 | 20.4 | 19.7 |
| **450** | 38.1 | 36 | 34.1 | 32.4 | 30.9 | 29.5 | 28.2 | 27. | 24.9 | 24. | 23.1 | 22.3 | 21.6 | 20.9 |
| **475** | 40.2 | 38 | 36. | 34.2 | 32.6 | 31.1 | 29.7 | 28.5 | 26.3 | 25.3 | 24.4 | 23.6 | 22.8 | 22.1 |
| **500** | **42.4** | **40** | **37.9** | **36.** | **34.3** | **32.7** | **31.3** | **30** | **27.7** | **26.7** | **25.7** | **24.8** | **24** | **23.2** |
| **525** | 44.5 | 42 | 39.8 | 37.8 | 36 | 34.4 | 32.9 | 31.5 | 29.1 | 28. | 26.9 | 25. | 25.2 | 24.4 |
| **550** | 46.6 | 44 | 41.7 | 38.6 | 37.7 | 36. | 34.4 | 33. | 30.5 | 29.3 | 28.3 | 27.3 | 26.4 | 25.5 |
| **575** | 48.7 | 46 | 43.6 | 41.4 | 39.4 | 37.6 | 36. | 34.5 | 31.9 | 30.7 | 29.6 | 28.5 | 27.6 | 26.7 |
| **600** | **50.8** | **48** | **45.5** | **43.2** | **41.1** | **39.3** | **37.6** | **36.** | **33.2** | **32.** | **30.8** | **29.8** | **28.8** | **27.8** |
| **625** | 52.9 | 50 | 47.4 | 45. | 42.9 | 40.9 | 39.1 | 37.5 | 34.6 | 33.3 | 32.1 | 31. | 30. | 29. |
| **650** | 55.1 | 52 | 49.3 | 46.8 | 44.6 | 42.5 | 40.7 | 39 | 36. | 34.7 | 33.4 | 32.2 | 31.2 | 30.2 |
| **675** | 57.2 | 54 | 51.2 | 48.6 | 46.3 | 44.1 | 42.3 | 40.5 | 37.5 | 36 | 34.7 | 33.5 | 32.4 | 31.3 |
| **700** | **59.3** | **56** | **53.1** | **50.4** | **48.** | **45.8** | **43.8** | **42** | **38.8** | **37.3** | **36.** | **34.7** | **33.6** | **32.5** |
| **725** | 61.4 | 58 | 55. | 52.2 | 49.7 | 47.4 | 45.1 | 43.5 | 40.2 | 38.7 | 37.3 | 36. | 34.5 | 33.6 |
| **750** | 63.5 | 60 | 56.9 | 54. | 51.4 | 49.1 | 47. | 45 | 41.5 | 40. | 38.6 | 37.2 | 36. | 34.8 |
| **775** | 65.6 | 62 | 58.8 | 56.3 | 53.1 | 50.7 | 48.5 | 46.5 | 42.9 | 41.3 | 39.9 | 38.5 | 37.2 | 36. |
| **800** | **67.8** | **64** | **60.6** | **57.6** | **54.9** | **52.4** | **50.1** | **48.** | **44.3** | **42.7** | **41.2** | **39.7** | **38.4** | **37.1** |
| **825** | 69.9 | 66 | 62.5 | 59.4 | 56.6 | 54. | 51.7 | 49.5 | 45.7 | 44 | 42.4 | 40.9 | 39.6 | 38.5 |
| **850** | 72. | 68 | 64.4 | 61.2 | 58.4 | 55.6 | 53.2 | 51. | 47.1 | 45.3 | 43.7 | 42.2 | 40.8 | 39.4 |
| **875** | 74. | 70 | 67.3 | 63. | 60. | 57.3 | 54.8 | 52.5 | 48.5 | 46.7 | 45. | 43.4 | 42. | 40.6 |
| **900** | **76.2** | **72** | **68.2** | **64.8** | **61.7** | **58.9** | **56.3** | **54.** | **49.9** | **48** | **46.3** | **44.6** | **43.2** | **41.8** |
| **925** | 78.4 | 74 | 70.1 | 66.6 | 63.4 | 60.5 | 57.9 | 55.5 | 51.3 | 49.3 | 47.6 | 46. | 44.4 | 42.9 |
| **950** | 80.5 | 76 | 72. | 68.4 | 65.1 | 62.2 | 59.5 | 57. | 52.6 | 50.7 | 48.8 | 47.1 | 45.6 | 44.1 |
| **975** | 82.6 | 78 | 73.9 | 70.2 | 66.8 | 63.8 | 61.0 | 58.5 | 54 | 52 | 50.2 | 48.4 | 46.8 | 45.3 |
| **1000** | **84.7** | **80** | **75.8** | **72.** | **68.7** | **66.** | **62.6** | **60.** | **55.4** | **53.3** | **51.4** | **49.6** | **48** | **46.4** |

# VENTILATION AND HEATING

## TABLE No. 9.

### Of the Areas of Circles and of the Sides of Squares of the Same Area.

| Diam. of Circle in Inches. | Area of Circle in square ins. | Sides of Sq. of same area in square ins. | Diam. of Circle in Inches. | Area of Circle in square ins. | Sides of Sq. of same area in square ins. | Diam. of Circle in Inches. | Area of Circle in square ins. | Sides of Sq. of same area in square ins. |
|---|---|---|---|---|---|---|---|---|
| 1. | .785 | .89 | 21. | 346.36 | 18.61 | 41. | 1320.26 | 36.34 |
| .½ | 1.767 | 1.33 | .½ | 363.05 | 19.05 | .½ | 1352.66 | 36.78 |
| 2. | 3.142 | 1.77 | 22. | 380.13 | 19.50 | 42. | 1385.45 | 37.22 |
| .½ | 4.909 | 2.22 | .½ | 397.61 | 19.94 | .½ | 1418.63 | 37.66 |
| 3. | 7.069 | 2.66 | 23. | 415.48 | 20.38 | 43. | 1452.20 | 38.11 |
| .½ | 9.621 | 3.10 | .½ | 433.74 | 20.83 | .½ | 1486.17 | 38.55 |
| 4. | 12.566 | 3.54 | 24. | 452.39 | 21.27 | 44. | 1520.53 | 38.99 |
| .½ | 15.904 | 3.99 | .½ | 471.44 | 21.71 | .½ | 1555.29 | 39.44 |
| 5. | 19.635 | 4.43 | 25. | 490.88 | 22.16 | 45. | 1590.43 | 39.88 |
| .½ | 23.758 | 4.87 | .½ | 510.71 | 22.60 | .½ | 1625.97 | 40.32 |
| 6. | 28.274 | 5.32 | 26. | 530.93 | 23.04 | 46. | 1661.91 | 40.77 |
| .½ | 33.183 | 5.76 | .½ | 551.55 | 23.49 | .½ | 1698.23 | 41.21 |
| 7. | 38.485 | 6.20 | 27. | 572.56 | 23.93 | 47. | 1734.95 | 41.65 |
| .½ | 44.179 | 6.65 | .½ | 593.96 | 24.37 | .½ | 1772.06 | 42.10 |
| 8. | 50.266 | 7.09 | 28. | 615.75 | 24.81 | 48. | 1809.56 | 42.58 |
| .½ | 56.745 | 7.53 | .½ | 637.94 | 25.26 | .½ | 1847.46 | 42.98 |
| 9. | 63.617 | 7.98 | 29. | 660.52 | 25.70 | 49. | 1885.75 | 43.43 |
| .½ | 70.882 | 8.42 | .½ | 683.49 | 26.14 | .½ | 1924.43 | 43.87 |
| 10. | 78.540 | 8.86 | 30. | 706.86 | 26.59 | 50. | 1963.50 | 44.31 |
| .½ | 86.590 | 9.30 | .½ | 730.62 | 27.03 | .½ | 2002.97 | 44.75 |
| 11. | 95.03 | 9.75 | 31. | 754.77 | 27.47 | 51. | 2042.83 | 45.20 |
| .½ | 103.87 | 10.19 | .½ | 779.31 | 27.92 | .½ | 2083.08 | 45.64 |
| 12. | 113.10 | 10.63 | 32. | 804.25 | 28.36 | 52. | 2123.72 | 46.08 |
| .½ | 122.72 | 11.08 | .½ | 829.58 | 28.80 | .½ | 2164.76 | 46.53 |
| 13. | 132.73 | 11.52 | 33. | 855.30 | 29.25 | 53. | 2206.19 | 46.97 |
| .½ | 143.14 | 11.96 | .½ | 881.41 | 29.69 | .½ | 2248.01 | 47.41 |
| 14. | 153.94 | 12.41 | 34. | 907.92 | 30.13 | 54. | 2290.23 | 47.86 |
| .½ | 165.13 | 12.85 | .½ | 934.82 | 30.57 | .½ | 2332.83 | 48.30 |
| 15. | 176.72 | 13.29 | 35. | 962.11 | 31.02 | 55. | 2375.83 | 48.74 |
| .½ | 188.69 | 13.74 | .½ | 989.80 | 31.46 | .½ | 2419.23 | 49.19 |
| 16. | 201.06 | 14.18 | 36. | 1017.88 | 31.90 | 56. | 2463.01 | 49.63 |
| .½ | 213.83 | 14.62 | .½ | 1046.35 | 32.35 | .½ | 2507.19 | 50.07 |
| 17. | 226.98 | 15.07 | 37. | 1075.21 | 32.79 | 57. | 2551.76 | 50.51 |
| .½ | 240.53 | 15.51 | .½ | 1104.47 | 33.23 | .½ | 2596.73 | 50.96 |
| 18. | 254.47 | 15.95 | 38. | 1134.12 | 33.68 | 58. | 2642.09 | 51.40 |
| .½ | 268.80 | 16.40 | .½ | 1164.16 | 34.12 | .½ | 2687.84 | 51.84 |
| 19. | 283.53 | 16.84 | 39. | 1194.59 | 34.56 | 59. | 2733.98 | 52.29 |
| .½ | 298.65 | 17.28 | .½ | 1225.42 | 35.01 | .½ | 2780.51 | 52.73 |
| 20. | 314.16 | 17.72 | 40. | 1256.64 | 35.45 | 60. | 2827.74 | 53.17 |
| .½ | 330.06 | 18.17 | .½ | 1288.25 | 35.89 | .½ | 2874.76 | 53.62 |

WEIGHT OF GALVANIZED IRON PIPE. As already stated, galvanized iron is almost exclusively employed for the making of large pipes, ducts and flues for the conduction of warm air. Its non-rusting qualities, and the large size of the sheets in which it may be purchased, make it, by all means, the best suited material for this purpose. Although straight, round pipe is frequently sold by the running foot, the ordinary practice in work at all complicated, as in the case of a heating and ventilating system, is to base the price upon the weight, the rate being at a given amount per pound. As prices have to be made in advance, it is evidently very necessary that one should be able to accurately estimate with comparative ease from a drawing the amount of material required.

To aid in such calculations Table No. 10 has been prepared, giving not only the weight of the galvanized iron per square foot, but also the weights per running foot for round pipe and the weight of elbows of corresponding sizes. This table may be relied upon as giving the maximum weight, due allowance having been made for laps and trimmings, as well as for rivets and solder; the general waste, for obvious reasons, cannot be included. The elbows are of the standard type previously described, having the internal radius of curvature equal to the diameter of the pipe itself. All of the weights are based upon the recently-adopted schedule of galvanized iron, in which the weights per square foot to some extent vary from those previously existing.

In ordinary heating and ventilating practice, it is customary to make round pipe in its various sizes upon gauges as follows: under 9 inch, No. 28 gauge; 9 to 14 inch, No. 26; 15 to 20 inch, No. 25; 21 to 26 inch, No. 24; 27 to 35 inch, No. 22; 36 to 46 inch, No. 20; 47 to 60 inch, No. 18; and all sizes above 60 inch of No. 16 gauge. If the pipe is made much lighter, particularly in the larger sizes, it will not keep its shape when laid horizontally, thereby seriously affecting the tightness of the joints and decreasing the area.

The common practice is to make rectangular pipes of the same gauge as round pipes having an equivalent area, but under certain conditions, as in the case of thin, flat pipe for overhead distribution in a basement, bracing is necessary to prevent the top and bottom from sagging even with heavy gauges. Therefore, with the bracing, gauges lighter than the ordinary may be used.

In calculating the weight of rectangular pipe, its superficial area, i.e., its perimeter in feet, multiplied by its length in feet, is taken as the basis, and special shapes are figured in a similar manner. The laps in rectangular pipe require more stock than in round pipe, and, therefore, from ten to twenty-five per cent. is added, according to the character of the pipe, to allow for this excess of material and for the weight of the necessary bracing and ribbing.

## TABLE No. 10.

### Of the Weight of Round Galvanized Iron Pipe and Elbows.

| Gauge and Wt. per Sq. Ft. | Diam. of Pipe. | Area in Sq. Ins. | Weight per Running Ft. | Weight of Full Elbow. | Gauge and Wt. per Sq. Ft. | Diam. of Pipe. | Area in Sq. Ins. | Weight per Running Ft. | Weight of Full Elbow. |
|---|---|---|---|---|---|---|---|---|---|
| No. 28 0.78 | 3 | 7.1 | 0.7 | 0.4 | No. 20 1.66 | 38 | 1134.1 | 18.2 | 139.4 |
| | 4 | 12.6 | 1.1 | 0.9 | | 39 | 1194.6 | 18.7 | 146.0 |
| | 5 | 19.6 | 1.2 | 1.2 | | 40 | 1256.6 | 19.1 | 152.9 |
| | 6 | 28.3 | 1.4 | 1.7 | | 41 | 1320.3 | 19.6 | 160.7 |
| | 7 | 38.5 | 1.7 | 2.3 | | 42 | 1385.4 | 20.1 | 168.6 |
| | 8 | 50.3 | 1.9 | 2.9 | | 43 | 1452.2 | 20.6 | 176.7 |
| No. 26 0.91 | 9 | 63.6 | 2.4 | 4.3 | | 44 | 1520.5 | 21.0 | 185.0 |
| | 10 | 78.5 | 2.7 | 5.3 | | 45 | 1590.4 | 21.5 | 193.4 |
| | 11 | 95.0 | 2.9 | 6.4 | | 46 | 1661.9 | 22.0 | 202.2 |
| | 12 | 113.1 | 3.2 | 7.6 | No. 18 2.16 | 47 | 1734.9 | 29.2 | 274.3 |
| | 13 | 132.7 | 3.4 | 8.9 | | 48 | 1809.6 | 29.8 | 286.6 |
| | 14 | 153.9 | 3.7 | 10.4 | | 49 | 1885.7 | 30.4 | 298.8 |
| No. 25 1.03 | 15 | 176.7 | 4.5 | 13.5 | | 50 | 1963.5 | 31.0 | 309.9 |
| | 16 | 201.1 | 4.7 | 15.1 | | 51 | 2042.8 | 31.6 | 322.5 |
| | 17 | 227.0 | 5.0 | 17.0 | | 52 | 2123.7 | 32.2 | 335.1 |
| | 18 | 254.5 | 5.3 | 19.1 | | 53 | 2206.2 | 33.0 | 349.7 |
| | 19 | 283.5 | 5.6 | 21.4 | | 54 | 2290.2 | 33.6 | 363.4 |
| | 20 | 314.2 | 6.0 | 23.9 | | 55 | 2375.8 | 34.4 | 377.2 |
| No. 24 1.16 | 21 | 346.4 | 7.0 | 29.6 | | 56 | 2463.0 | 34.9 | 390.7 |
| | 22 | 380.1 | 7.3 | 32.3 | | 57 | 2551.8 | 35.6 | 405.1 |
| | 23 | 415.5 | 7.7 | 35.6 | | 58 | 2642.1 | 36.1 | 418.8 |
| | 24 | 452.4 | 8.0 | 38.6 | | 59 | 2734.0 | 36.7 | 433.1 |
| | 25 | 490.9 | 8.3 | 41.7 | | 60 | 2827.4 | 37.4 | 448.6 |
| | 26 | 530.9 | 8.7 | 45.1 | No. 16 2.66 | 61 | 2922.5 | 46.7 | 569.7 |
| No. 22 1.41 | 27 | 572.6 | 10.9 | 59.1 | | 62 | 3019.1 | 47.5 | 589.0 |
| | 28 | 615.7 | 11.4 | 64.2 | | 63 | 3117.3 | 48.3 | 608.6 |
| | 29 | 660.5 | 11.8 | 68.6 | | 64 | 3217.0 | 49.1 | 628.5 |
| | 30 | 706.9 | 12.2 | 73.4 | | 65 | 3318.3 | 49.8 | 647.4 |
| | 31 | 754.8 | 12.6 | 78.3 | | 66 | 3421.2 | 50.5 | 666.6 |
| | 32 | 804.3 | 13.0 | 83.4 | | 67 | 3525.7 | 51.3 | 687.4 |
| | 33 | 855.3 | 13.5 | 88.9 | | 68 | 3631.7 | 52.1 | 708.6 |
| | 34 | 907.9 | 13.9 | 94.3 | | 69 | 3739.3 | 52.8 | 728.6 |
| | 35 | 962.1 | 14.3 | 99.9 | | 70 | 3848.5 | 53.6 | 750.4 |
| No. 20 1.66 | 36 | 1017.9 | 17.2 | 124.4 | | 71 | 3959.2 | 54.3 | 771.0 |
| | 37 | 1075.2 | 17.8 | 131.4 | | 72 | 4071.5 | 55.1 | 793.4 |

MIXING DAMPERS. With the advent of the hot and cold or double duct system there arose the necessity of a simple contrivance to coincidently regulate the volume of air discharged from the two ducts. Two methods of regulation appear: first, that by which full volumes of cold air and of warm air are alternately admitted; and second, that by which a damper is so constructed and adjusted as to permit the air of the two temperatures to produce a constant mixture of the desired temperature. If, by the first method, the alternations are sufficiently rapid, the room is maintained at practically a constant temperature, but if less frequent the tendency is toward fluctuation between extremes, although the proper average may be maintained.

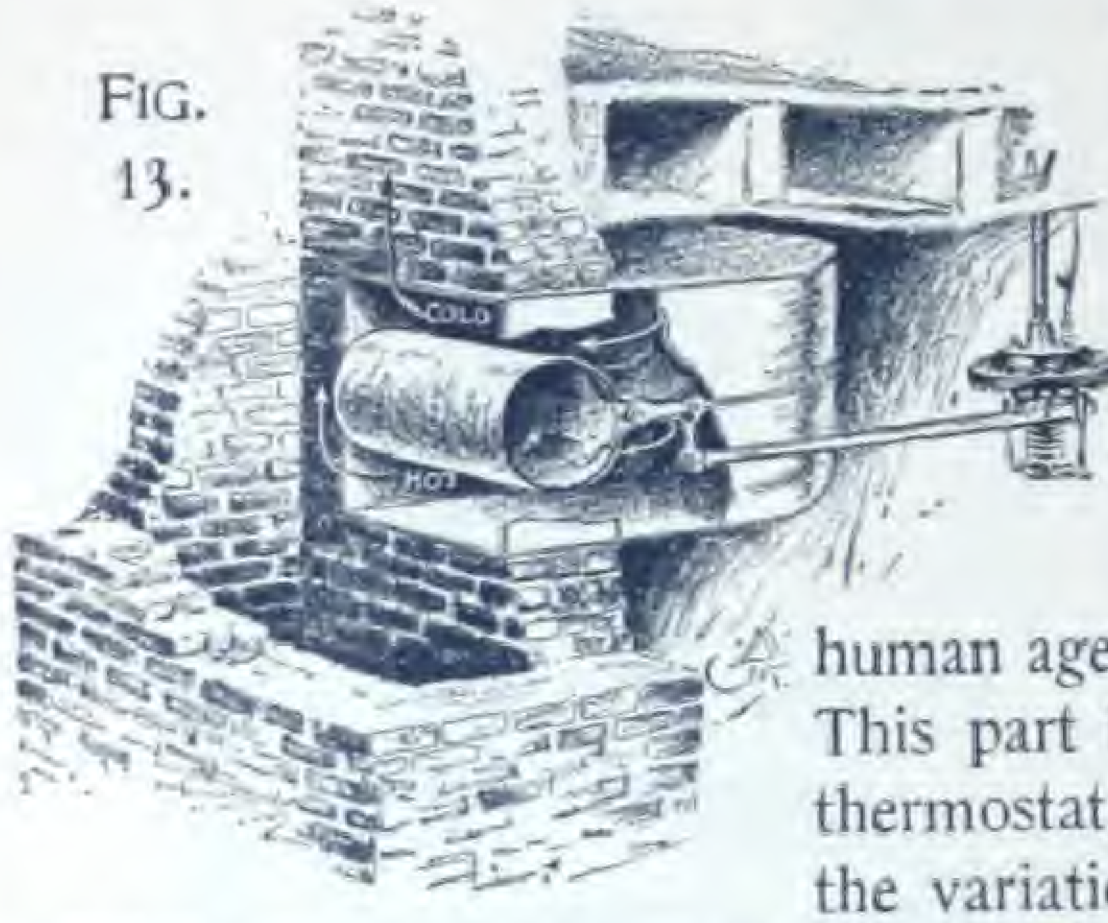
FIG. 11.

Obviously, the first type of damper is impracticable for operation by hand, for it would require constant attention. For hand regulation the second type must, therefore, be adopted; and, for perfect action, it must so admit the air volumes relatively to each other, that one shall be decreased proportionally as the other is increased, and thus cause the volume to continue constant. This requirement is met in the Sturtevant mixing damper, which, being of cylindrical form, of necessity fulfils this function. As ordinarily arranged for hand regulation, it is shown in Fig. 11, in connection with a system of overhead ducts suspended just below the basement ceiling. The damper proper swings in a cast iron frame, which may be bricked into the wall, and to which the double system of ducts may be connected. From the cylinder, which is pivoted as shown, there extends up the flue a chain, which, after passing over a guide pulley, is conducted into the room at some three or four feet above the floor, there to be operated at the will of the occupants.

FIG. 12.

When the air is conducted beneath the basement floor, the arrangement of ducts and damper is as shown in Fig. 12. Under these

FIG. 13.




conditions proper manholes should be provided to permit of access to the ducts.

Although the temperature of a given apartment may, by such means, be maintained very near a stated temperature, the mixing damper may, under certain conditions, require such attention that the desirability of some other than human agency may seem desirable for its operation. This part is played, and most perfectly too, by the thermostat, which, operating under the influence of the variations in temperature of the room, acts to produce converse action of the mixing damper. That is, as the room temperature increases, the volume of cold air admitted is increased, while the warm air is correspondingly decreased.

When regulation of temperature is to be secured by a maintained mixture of the hot and cold air, the type of damper previously illustrated is employed. In Fig. 13 is represented such a damper operated gradually by a thermostat, acting through a system of levers. With such a type of damper, it is possible to supply, through the cold air duct, air that has acquired no heat other than that taken up in its passage through the duct to the damper. But, if so supplied, the damper must be capable of shutting it off completely, if occasion demands that a full supply of hot air only shall be delivered to the room to maintain the desired temperature. This is attained in the Sturtevant mixing dampers by packing the cylinder with felt in such a manner as to prevent all leakage of cold air when closed against its supply.

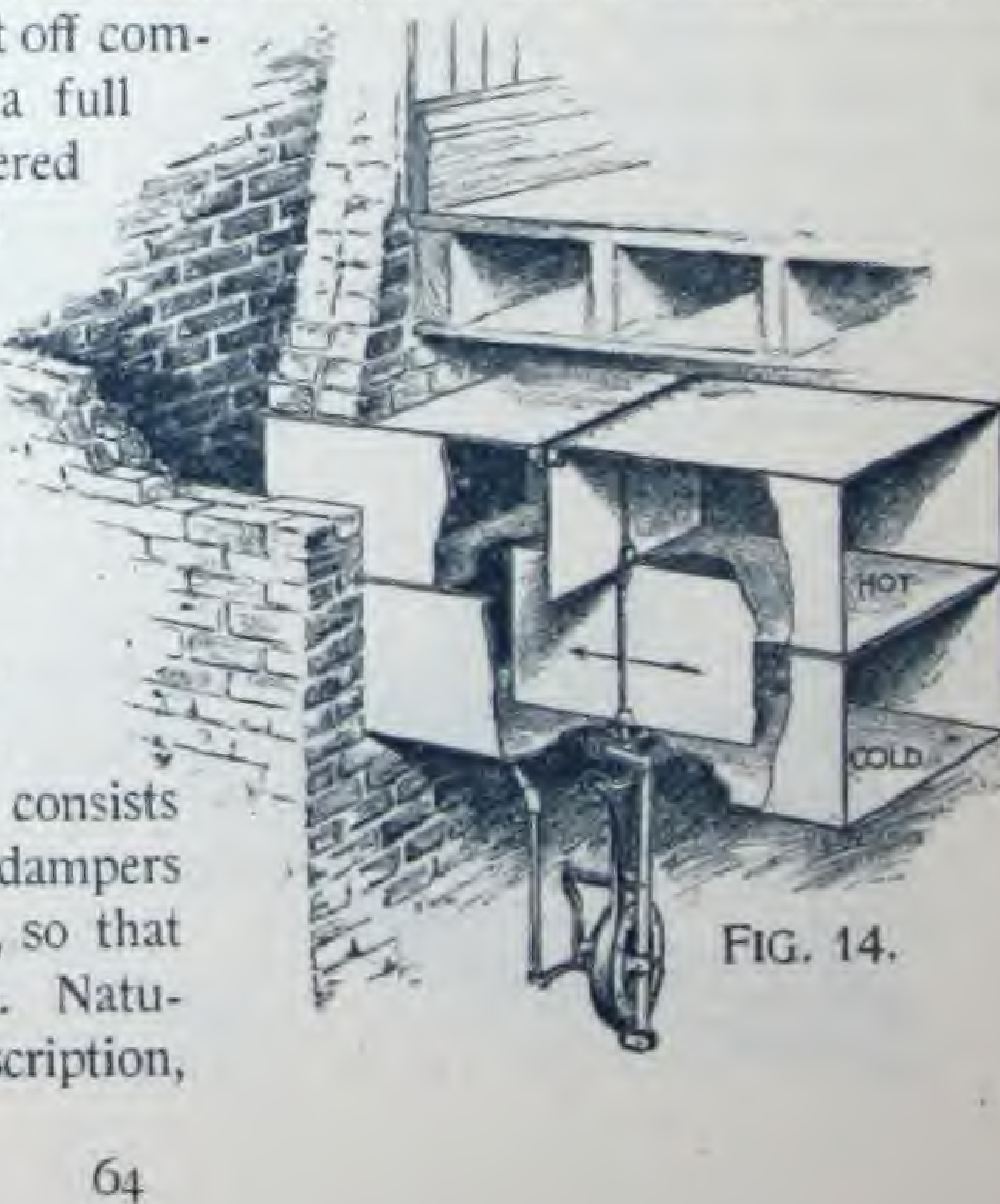



FIG. 14.

For intermittent operation the type of damper shown in Fig. 14 is frequently employed. This consists merely of two straight butterfly dampers set at right angles to each other, so that when one is closed the other is open. Naturally with a damper of this description,

operating to alternately admit cold and warm air, the relative temperature of the cold air should be only a little below that of the room to which it is supplied, for otherwise too sudden cooling and objectionable draughts would be caused. It is, therefore, necessary under these conditions to provide, in connection with the main apparatus, a tempering-coil through which all of the air shall pass, and from which volume the supply for the so-called cold-air duct shall be taken.

A damper of this type is not desirable for gradual adjustment where a constant mixture is maintained; first, because it is inherently incapable of keeping the total volume constant with the varying relative volumes of hot and cold air; and second, because, as ordinarily constructed, it does not shut tight against the cold air supply.

ADVANTAGES OF THE STURTEVANT SYSTEM. The advantages of the Sturtevant System, although incidentally mentioned in the preceding pages, may here be summarized under two main heads:

First, adaptability and convenience.

Second, efficiency and economy.

The early consideration of the system before the plans of the building are completed has, of course, much to do with its adaptability and the convenience with which it may be introduced.

The centralizing of the entire heating surface in a single room and within a single sheet-iron jacket avoids all danger by fire, prevents the possibility of damage by leakage, and removes all anxiety regarding the freezing incident to isolated coils. A single valve serves to control the temperature of all air admitted to the building, so that the thoroughly installed system, with its governed engine, self-oiling devices, automatic return water apparatus, damper regulator, and its thermostatic control, is rendered so completely self-controlling that the attendant's care is usually reduced to supplying sufficient coal to the boiler.

The system is positive in its action at all times, the air is put where it is wanted, not merely allowed to go. The pressure created within the building is sufficient to cause all leakage to be outward, preventing cold inward draughts and avoiding the possibility of drawing air from any polluting source within the building itself.

Absolute control may be had over the quality and quantity of air supplied. It may be filtered and cleansed, heated or cooled, dried or moistened at will. By means of the hot and cold mixing damper, the temperature of air admitted to any given apartment may be instantly and radically changed.

# VENTILATION AND HEATING

The *efficiency* and *economy* of the system must of necessity be considered under *first cost* and *running expense*.

Circumstances so decidedly alter cases that an arrangement economical and easy of introduction in one building may prove very expensive in another. In most cases, however, the Sturtevant System, regarded simply as a method of heating, may be installed for less money than any other system of equal efficiency. Wherever the flues can be formed in the walls and the distributing ducts are of moderate extent, the system will figure less in first cost than any other capable of attaining the same results and of supplying the same amount of air. The primary cost of a fan is less than that of any other device for moving the same amount of air.

The large volume of air passing through the heater causes a condensation of steam so great that one foot of heating surface is rendered the equivalent in efficiency of three to five feet in the form of the ordinary direct radiator exposed in the room. This saving in heating surface offsets the additional cost of fan and motor. As bearing directly upon this point, Professor Woodbridge* has stated with regard to the installation in the Walker Building, of the Mass. Institute of Technology, that the saving in piping due to rapid condensation in the coils, as there arranged, was sufficient to pay for the fan, as well as an attached engine, had the latter been adopted.

In all fairness, the operating expenses of any system must be compared upon a basis of similar conditions. The Sturtevant System, when taking its air from out-of-doors, cannot be properly compared with any system of direct radiation, for in the latter is lacking the advantage of the ventilation incidental to the operation of the former. But when the Sturtevant System rehandles and reheats the air within the building without outside supply, the comparison becomes more reasonable, although there will still continue to be a considerable change of air due to leakage.

A six months' continuous test at the Globe Yarn Mills, Fall River, has presented data exceptionably valuable for comparison, as indicated in the accompanying record for the period October 15, 1888, to March 15, 1889:

| | MILL NO. 1. | MILL NO. 2. |
|---|---|---|
| Average temperature | 70° | 78° |
| Coal burned for heating | 317,000 lbs. | |
| Coal burned for heating, ventilating and moistening | | 286,900 lbs. |
| Coal burned per 1,000 cubic feet of space | 340.26 lbs. | 217.92 lbs. |
| Ratio | 100 | 64 |
| | 156 | 100 |

*Technology Quarterly, Vol. II, No. 1.

# VENTILATION AND HEATING

Mill No. 1 was heated by direct steam, with overhead pipes. Mill No. 2, which stood beside, and contained 212,668 cubic feet more than Mill No. 1, was equipped with the Sturtevant System. It is to be noted that in the mill heated by the Sturtevant System, a temperature of 78° was maintained as against 70° in the other mill, while the total amount of coal consumed for its threefold duty of heating, ventilating and moistening was only sixty-four per cent. of the cost of merely heating the other mill.

The cost of janitorial service enters as an important factor in any building other than a manufactory. The Sturtevant System has been adversely criticised because of the experience required in its operation. In point of fact, it has been attempted by committees and school boards to place the control of the system in the hands of men who could sweep floors and shovel coal, but scarcely knew the difference between a boiler and an engine. It is not greater intelligence, but a different order of intelligence, that is required.

When exhaust steam that would otherwise be thrown away is utilized in the heater, its cost must be considered as practically nothing. The condensation in the heater of all the exhaust steam from the special fan engine reduces the cost for motive power to a minimum.

As to comparisons regarding cost of repairs, much may be said pro and con; but the character of the machinery, its few parts, slow speed of engine and fan, the sectional construction of the heater, the lack of complication of valves, the concentration of the plant at one point, and the fact that it is under the care of one man, are greatly in its favor.

THE DESIGN OF HEATING AND VENTILATING SYSTEMS. It must appear from the preceding pages that the proper design of a satisfactory system of heating and ventilation is no simple matter. It is neither a question of theory nor of practice, the one independent of the other, but such a comprehensive knowledge of the entire matter is necessary that certainty of result may be assured. As the demands for improved ventilation have increased, the problem has grown more and more complicated until it has become an evident fact that no public building of reasonable size should be trusted to other than an expert of established reputation.

As a consequence, the architect looks either to an expert engineer, or to a reputable and experienced house, to develop the plans for the heating and ventilation. The B. F. Sturtevant Co. has now been directly connected with this class of work for nearly a third of a century, has fostered and established the general system of heating and ventilation by a forced circulation of warm

air, and stands to-day in the fore-front of those who are prepared and qualified to undertake the largest contracts wherein the fan is an essential feature. The Sturtevant System has been upheld because it is theoretically, logically and practically *the best*, and the sincere desire of this house has always been that the System should win upon its merits. The extensive business of to-day certainly testifies to the fact that such has been the case.

The B. F. Sturtevant Co. solicits inquiry from all parties interested in improved methods of heating and ventilation; it cheerfully furnishes complete plans and specifications for all buildings whose character would warrant the introduction of the System, and is prepared to take contracts, under its own or others' specifications, for any portion or the whole of the work of heating and ventilating where a fan is employed.

# VENTILATION AND HEATING

## THE STURTEVANT

# HEATING AND VENTILATING APPARATUS.

UPON the pages immediately following are presented, in as concise form as possible, descriptions and illustrations of the more important and characteristic types of apparatus manufactured by this house for the purposes of heating and ventilation. Special types and more detailed descriptions will be found in other catalogues published by this Company, and, wherever necessary, special designs will be furnished.

The component parts of the Sturtevant Heating and Ventilating Apparatus are a Fan Wheel, enclosed or not as best suits the circumstances, and arranged to be driven either by belt or by direct connection by means of some form of motor, preferably a Steam Engine or Electric Motor; a Steam Heater, across which the air is forced or drawn; and a Return Water Apparatus, consisting of a steam trap or of a pump and receiver arranged to operate automatically.

## FANS.

THE FAN WHEEL. As constructed for ordinary ventilating purposes, the fan wheel consists of a series of T steel arms cast into a hub and carrying the floats or blades, which, together with the side plates of the wheel, are constructed of light but strong steel plate, substantially as shown in Fig. 15. Here, as is the case with all wheels above the smaller sizes, two hubs are used. This construction combines the minimum of weight with the maximum of strength and durability, and is especially designed to meet the requirements of a ventilating fan, namely, ability to handle the largest volumes of air, at low pressure, with the least expenditure of power. The wheel is carried by a stiff steel shaft supported in the Sturtevant patent brush oiler boxes. Constructed with the greatest care, of the best materials, and containing an oil reservoir from which the oil is continuously fed to the journal by the brushes, this box is at once *unheatable*, is capable of universal adjustment, and once filled with oil may be run for weeks without further attention.

Although this type of fan may be used without a casing where properly arranged in connection with a supply opening, it is almost universally employed wherever the wheel is to be encased, whether in sheet metal, brick or wood. Evidently a sheet metal casing may be almost as readily constructed in one form as another, so that all locations of discharge are possible, and complete steel plate housings may be readily made to conform to given and special designs. As ordinarily built, either to be driven by pulley or by direct connected engines, these various shapes of housings are illustrated on subsequent pages.

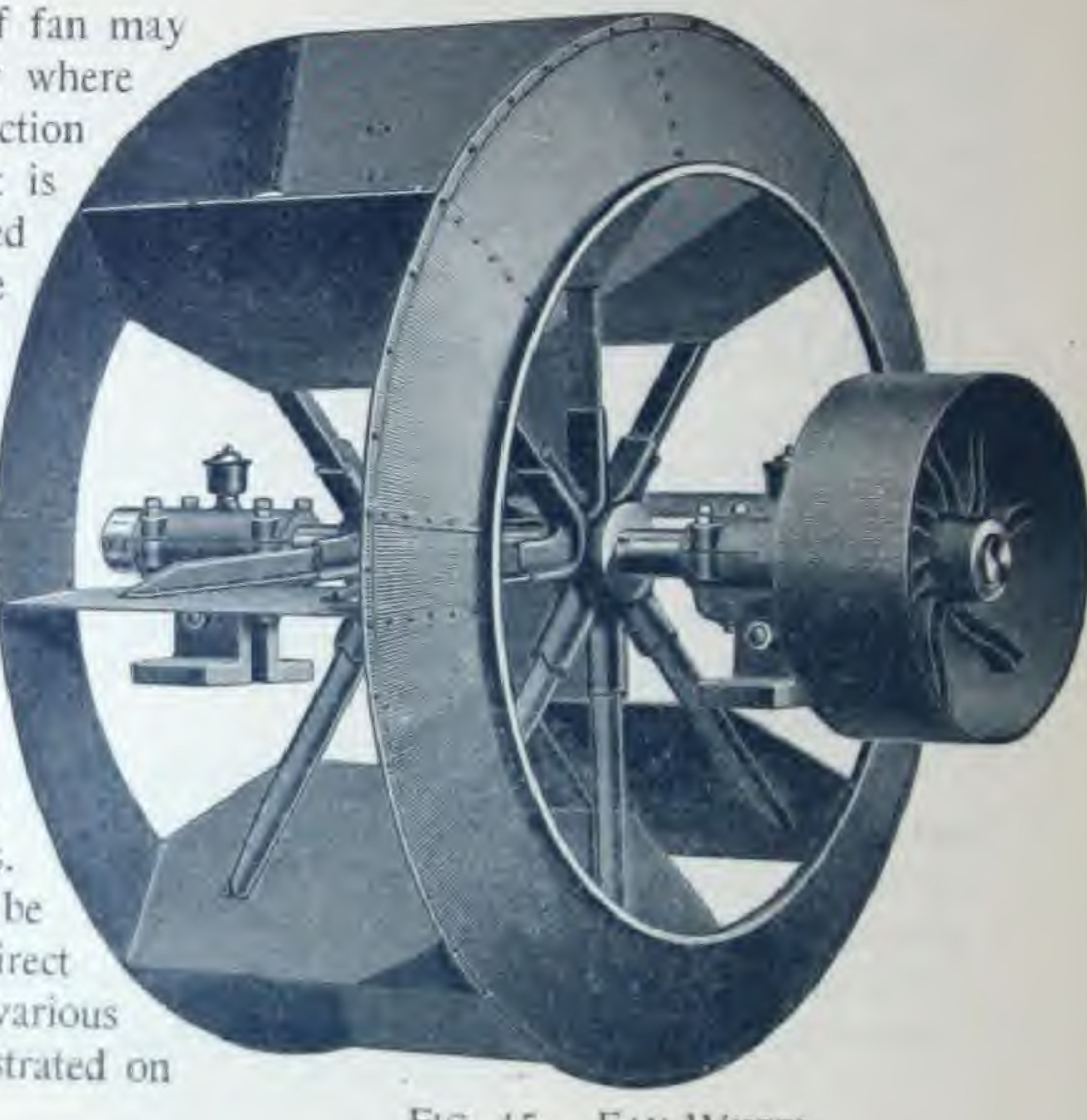


FIG. 15. FAN WHEEL.

DISC WHEEL. When air is to be moved against very slight resistance, as is the case where exhaust ventilation is to be accelerated, the disc or propeller form of wheel, as illustrated in Fig. 16, is of great service. This wheel, light in its construction, consuming but little power at low speeds, and very easily erected, is exceedingly convenient for introduction in the attic or upper story of a building, where it may be driven by belt from an adjacent electric motor. Under such an arrangement, it is usually installed at the junction of the connections from the ventilating flues in such a manner that when not in operation there is very little obstruction offered to the flow of air by natural means.

For certain locations this fan is fitted with a special type of horizontal engine, as shown in Fig. 17, readily installed upon a projecting shelf. Thus arranged it may be employed as a plenum fan, to force air into a building. But great discretion should be exercised in its introduction for such a purpose, for it lacks ability, except at excessive expenditure of power, to force air through a complicated system of distributing ducts.

CONE FAN. Wherever a fan wheel is to be used without casing and under conditions that require anything above the most moderate air pressure, the cone fan is particularly desirable. As ordinarily installed, it is placed close up to a division wall in which is located an inlet opening concentric with the inlet of the wheel. The air is thus drawn from one side of the wall and delivered into a space of greater or lesser extent upon the other side, where the fan is located. As ordinarily constructed and located, the type of fan is clearly shown in Fig. 18. The base of this wheel is a conoidal iron casting with its apex toward the opening in the wall, so that the air entering the wheel is gradually deflected toward the numerous curved blades which extend outward from the conoid, and are so attached to the back plate as to make a very stiff machine. A bar across the inlet, and a trussed support on the back, carry the necessary journal boxes. Such a cone fan possesses marked advantages over a disc fan in that it will deliver air against resistance; back-lash is impossible, and the centrifugal force of the blades is utilized. At a given peripheral speed the cone fan will give far superior results in volume of air moved and in proportional power expended.

FIG. 16. DISC WHEEL.

Large numbers of these cone wheels, constructed to conform to proportions dictated by Prof. S. H. Woodbridge, have been furnished under specifications drawn by him for prominent buildings throughout the country.

When a sub-basement is to be kept filled with air under slight pressure,— as in the plenum system already described,— this fan is very economical and convenient, as no connecting ducts are required, the fan simply standing in the sub-basement and delivering directly into it. If desired, the wheel can be fitted with a direct-connected engine placed upon the back side of the wheel; or, if circumstances require it, the wheel may be arranged upon a vertical shaft, with step bearing, and driven by belt.

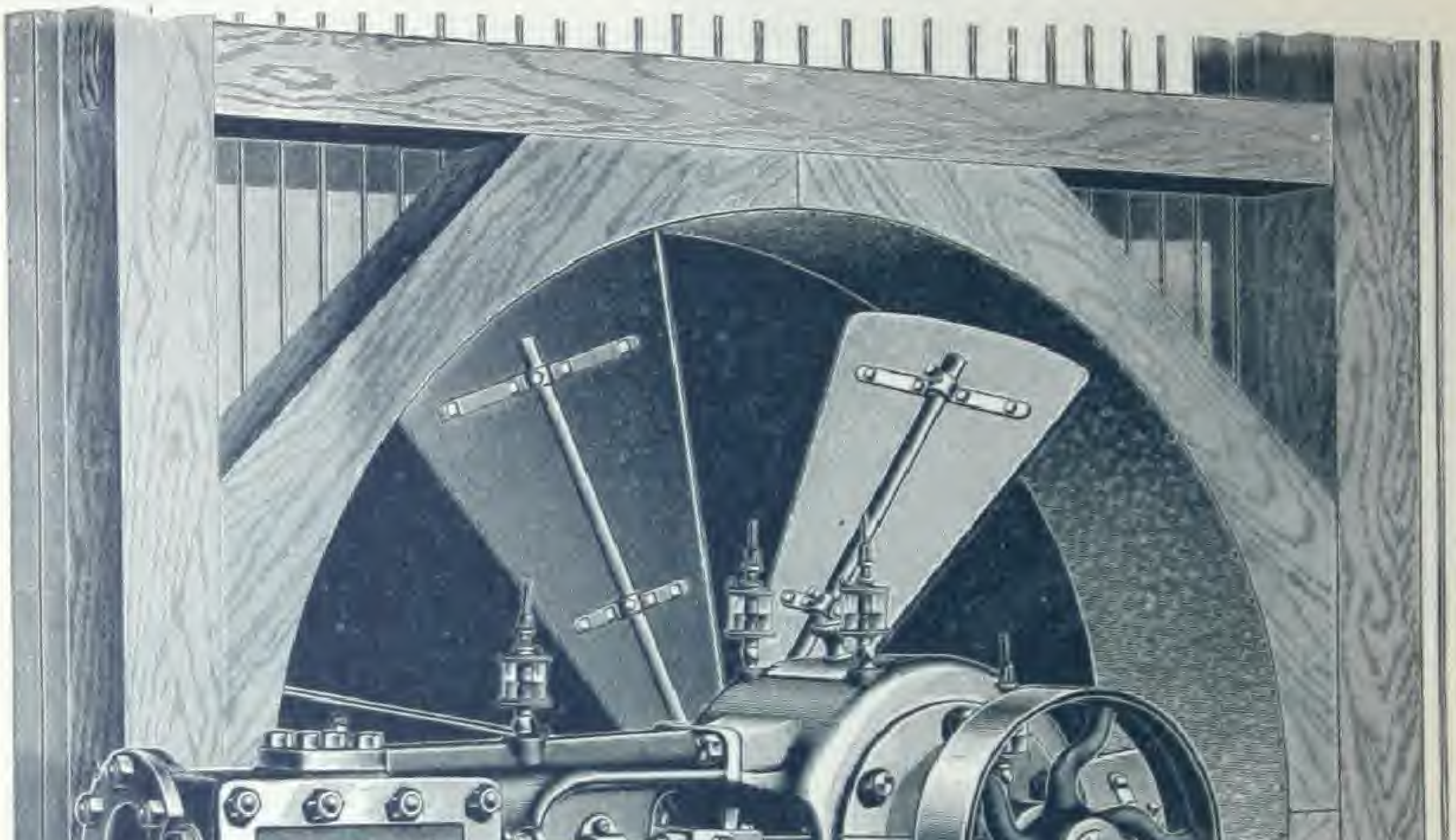



FIG. 17. DISC WHEEL,
WITH HORIZONTAL ENGINE.

FIG. 18. CONE WHEEL.

MONOGRAM EXHAUSTER. The most substantial form of enclosed exhaust fan is shown in Fig. 19. The shell is entirely of cast iron, the supporting hanger for the journal boxes being bolted thereto. Both bearings, which are of exceptional length and arranged for thorough oiling, are placed upon one side of the fan, leaving the inlet upon the other side entirely unobstructed for the entrance of air. It is this feature that distinguishes an exhauster from a blower, for the latter usually has a bearing upon each side and always has two inlet openings, one upon either side, while an exhauster has only a single inlet, and that upon the side opposite to the pulley.

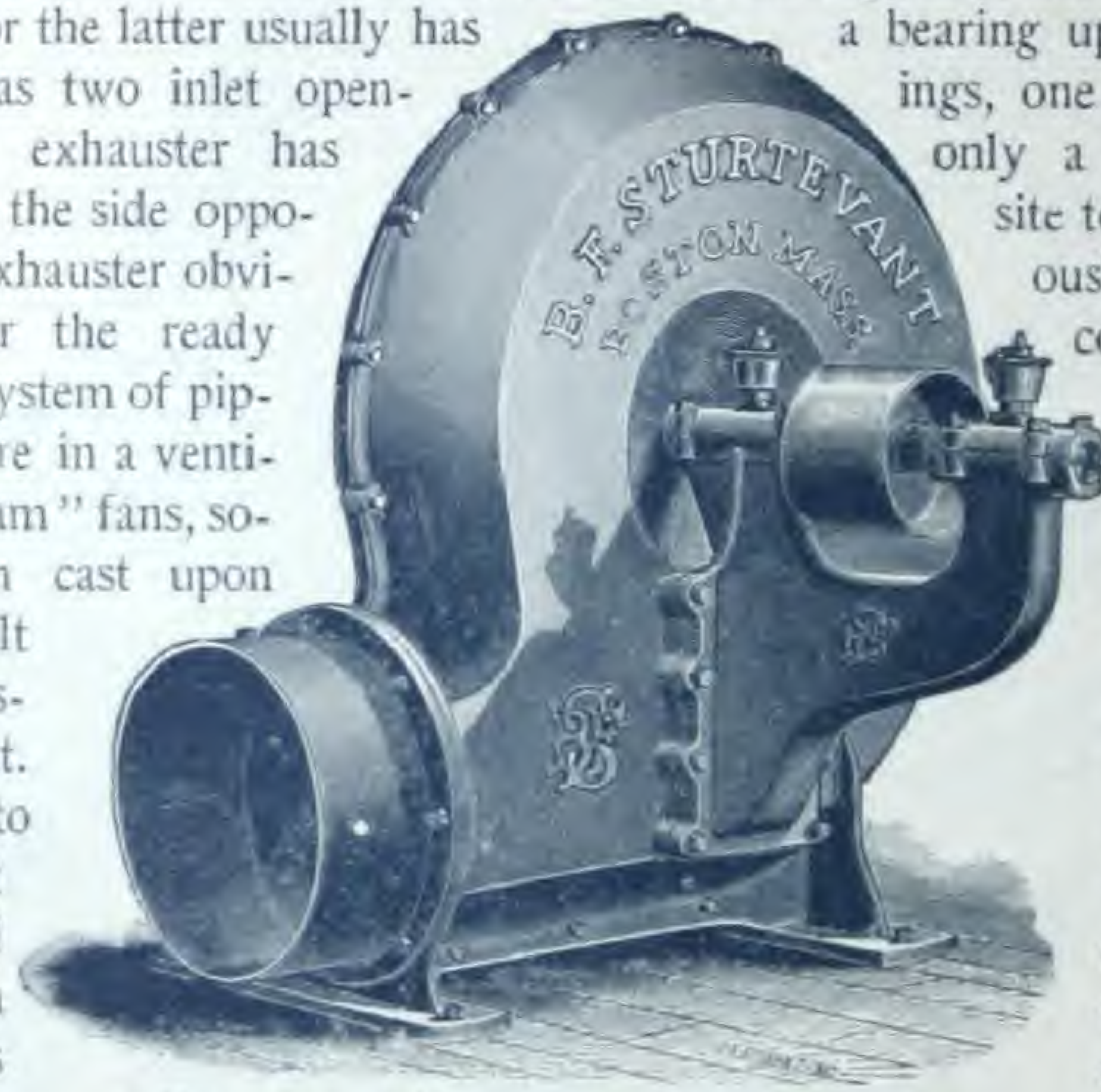



FIG. 19. "MONOGRAM" EXHAUSTER.

An exhauster obviously provides opportunity for the ready connection of its inlet to a system of piping, a very necessary feature in a ventilating plant. The "Monogram" fans, so-called from the monogram cast upon the side, are regularly built with bottom horizontal discharge, as shown in the cut. They can be constructed to discharge horizontally at the top,—directly upward or directly downward when occasion demands.

Fans are designated as right or left-hand according as the pulley, engine or motor is upon the right or left-hand side as one faces the outlet. The illustration shows a right-hand bottom horizontal exhauster. The various discharges and hands of fans are indicated upon succeeding pages, showing outlines of steel plate steam fans.

The capacity of the "Monogram" fans is relatively small, even in the larger sizes, when compared with the capacity of some of the large steel plate fans. The former type is, however, extremely serviceable for the ventilation of small apartments, or for forcing or drawing air through long and comparatively small conduits where the resistance to be overcome enters as an important element. Under these circumstances the particular value of this fan lies in the character of its design, for it may be run continuously and noiselessly at the high speed necessary to produce the requisite pressure.

STEEL PLATE PULLEY FAN. For the general purposes of mechanical ventilation the steel plate cased fan is now almost universally employed. The pulley fan, as constructed in the smaller sizes, is of the form shown in Fig. 20. The sides and rim are of steel plate, built up on a cast-iron base and provided with a round outlet casting. The shaft, pulley and fan wheel are all supported by an independent "hanger" which is attached to the side of the fan, but also rigidly bolted to the floor when in position. The wheel is thus overhung on the shaft, and the inlet left free for the passage of air.

In the larger sizes the construction shown in Fig. 21 is adopted. The sides are braced by angle iron, and upon each side is a supporting truss which carries a journal box. The shaft thus projects entirely though the fan, and the pulley is overhung upon one end. In the illustration a blower is shown, there being an inlet upon each side. Closing the inlet upon the pulley side would transform it into a right-handed exhauster, and render it, like Fig. 20, capable of attachment to a piping system.

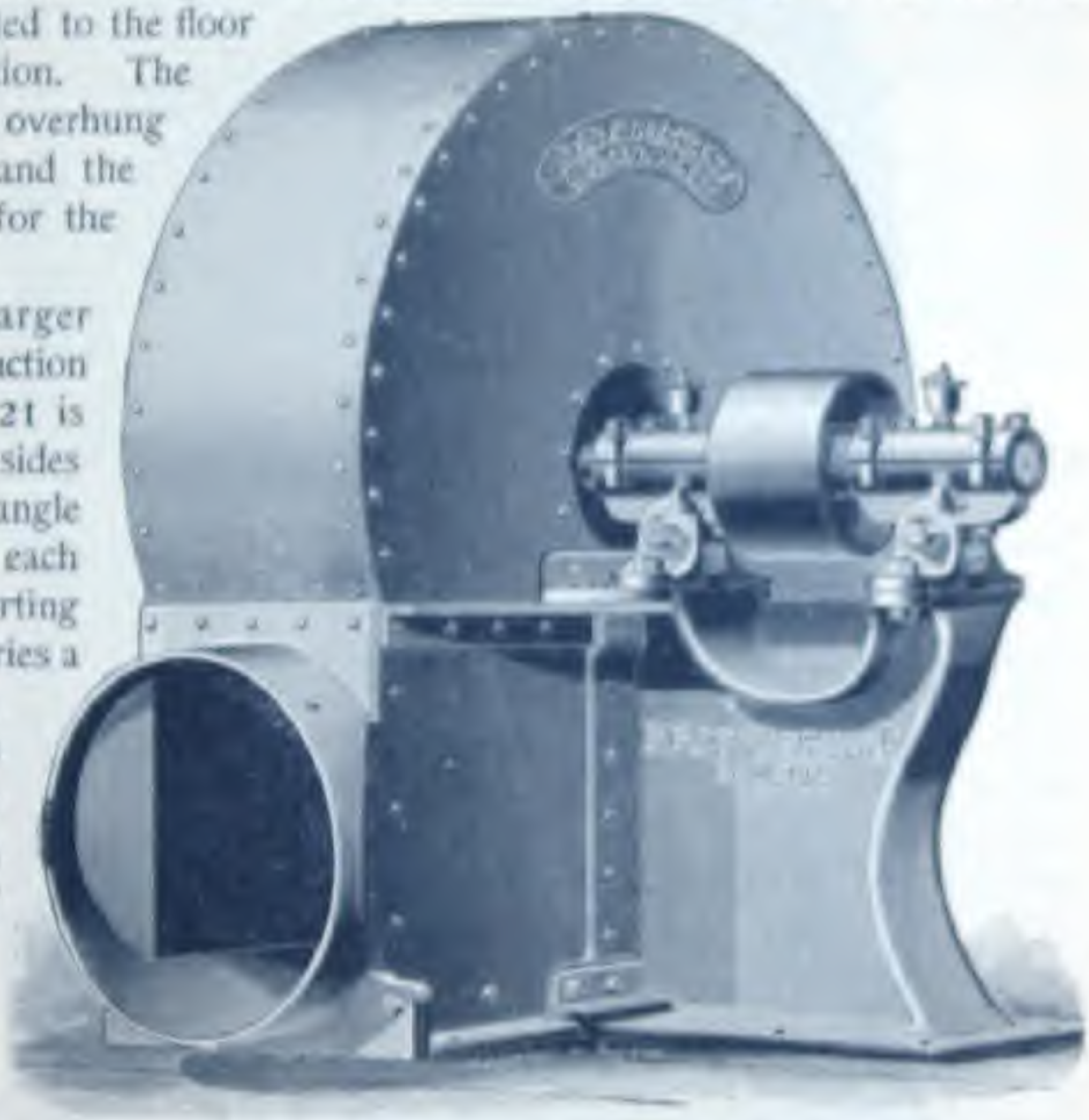


FIG. 20. STEEL PLATE PULLEY EXHAUSTER, WITH OVERHUNG WHEEL.

The standard forms of steel plate fans are well shown in the succeeding illustrations of steam fans. It is evident, however, that any arrangement of discharge is possible, and that the material of construction makes it a comparatively simple matter to conform to any special design to suit the most exacting conditions.

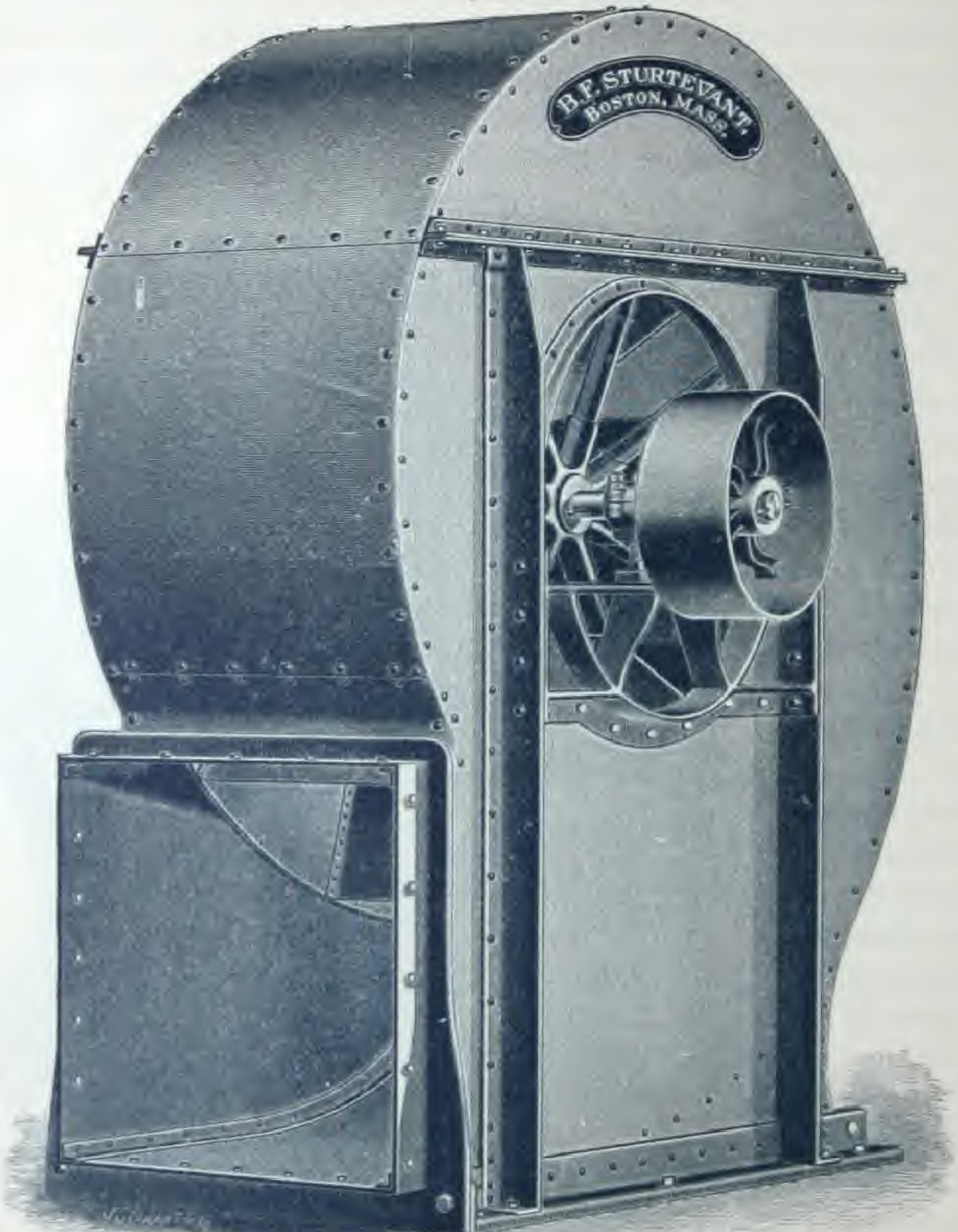



FIG. 21. STEEL PLATE BLOWER,
WITH OVERHUNG PULLEY.

# VENTILATION AND HEATING

ELECTRIC FAN. The rapidly-increasing adoption of electricity as a motive power renders possible the introduction of the electric fan with every assurance of success. Whereas, heretofore, it has usually been necessary to provide a steam engine for the propulsion of a fan, it is now a simple matter to install a fan with either direct-connected or independent motor.

For convenience, as well as economy, the electric fan with motor directly attached presents itself as by far the most desirable. It is thus rendered compact and portable, may be located in any position, and occupies the mimimum of space.

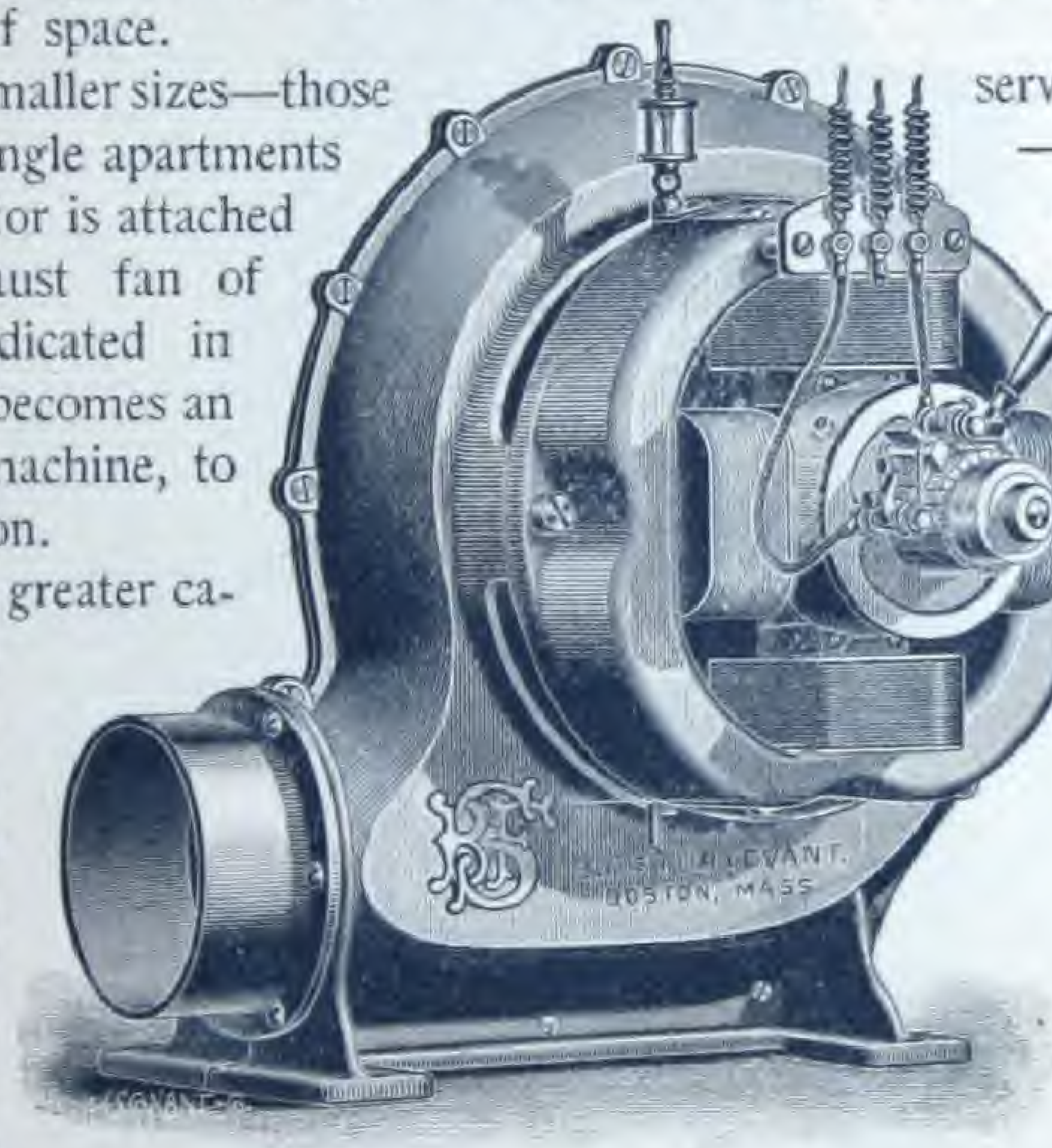


FIG. 22.
" MONOGRAM " ELECTRIC EXHAUSTER.

In the smaller sizes—those serviceable for the ventilation of single apartments—a specially constructed motor is attached directly to the side of an exhaust fan of the " Monogram " type as indicated in Fig. 22. The motor thus becomes an integral part of the entire machine, to be adapted to any given location.

Where greater capacity is required, the steel plate fan is fitted with a motor after the manner of Fig. 23. Evidently, as in the case of all steel plate fans, any design in the matter of shape and discharge may be followed, the motor remaining the same. Such a fan fulfils all the requirements for heating and ventilating, and may be readily installed in connection with a heater, thus forming a steam hot blast apparatus.

But the use of such a fan is necessarily largely in locations where a movement of air is desired at its natural temperature, that is, independent of the heating system. If the fan is to be used where steam of any reasonable pressure is employed for heating, it must be obvious that the simplest and most economical arrangement would call for an engine to drive the fan, for the exhaust steam could all be utilized for heating purposes.

For use in the form of an exhaust fan, as an adjunct to a plenum system

of heating, the electric fan is, however, frequently of great service. It may be easily installed and operated in an out-of-the-way position as in any other, and can be arranged to be started and stopped from a switchboard in a much more convenient location, so that the attendant will seldom have to visit the fan.


FIG. 23. STEEL PLATE ELECTRIC EXHAUSTER.

STEAM FAN. It is always desirable that the means of propulsion for a fan should be rendered as independent as possible of any other source of power; in other words, that the motor adopted should be devoted solely to the driving of the fan. Although the electric motor, as already pointed out, is being very

generally introduced, the steam engine stands as the almost universal agent for fan propulsion, the combination of fan and engine being designated a steam fan.

As constructed of steel plate in the smaller sizes, the shell and wheel are identical with those used for a pulley fan. In the place of the pulley and its hanger, however, there is provided a special type of centre-crank upright engine, with its cylinder above the shaft, supported upon a substantial base and carrying the fan wheel overhung upon the end of its shaft, all as illustrated in Fig. 24. In the larger sizes of full housing steam fans, the engine is of an entirely different form, as shown in Fig. 25, having its cylinder beneath the shaft, the opposite end of which is supported by a box in the inlet of the fan. Both types of engines are particularly designed for this work, are of a high grade of workmanship, and are capable of sustained operation at high speed.

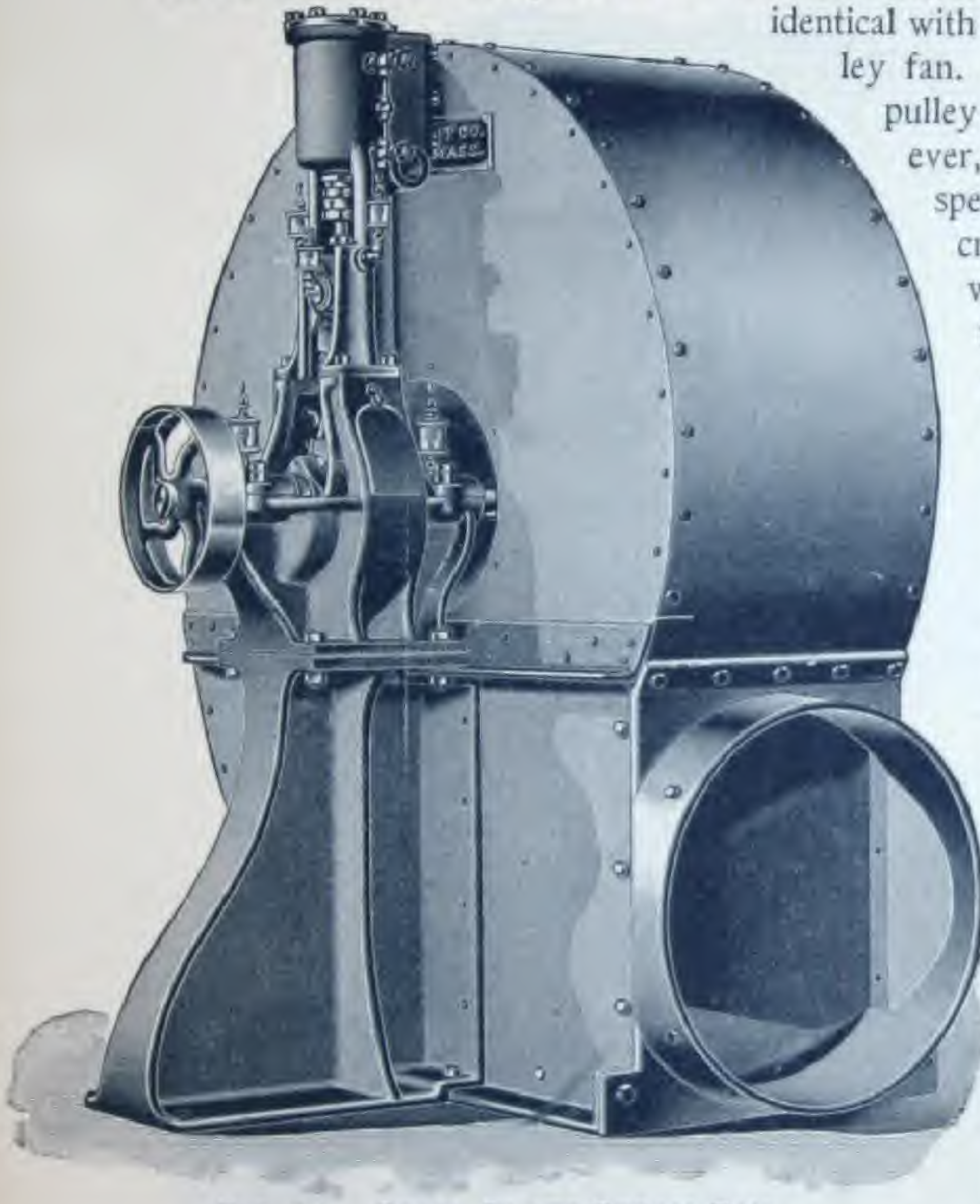


FIG. 24. STEEL PLATE STEAM FAN.

Where exceptional durability or steadiness in running is desired, or where it is necessary to drive the fan above the ordinary speed, the type of steam fan shown in Fig. 26 is very efficient, the engine being double-cylindered and of the very highest grade. The outline cuts, Figs. 27 to 34, are self-explanatory of the standard forms in which all steel plate fans are constructed.

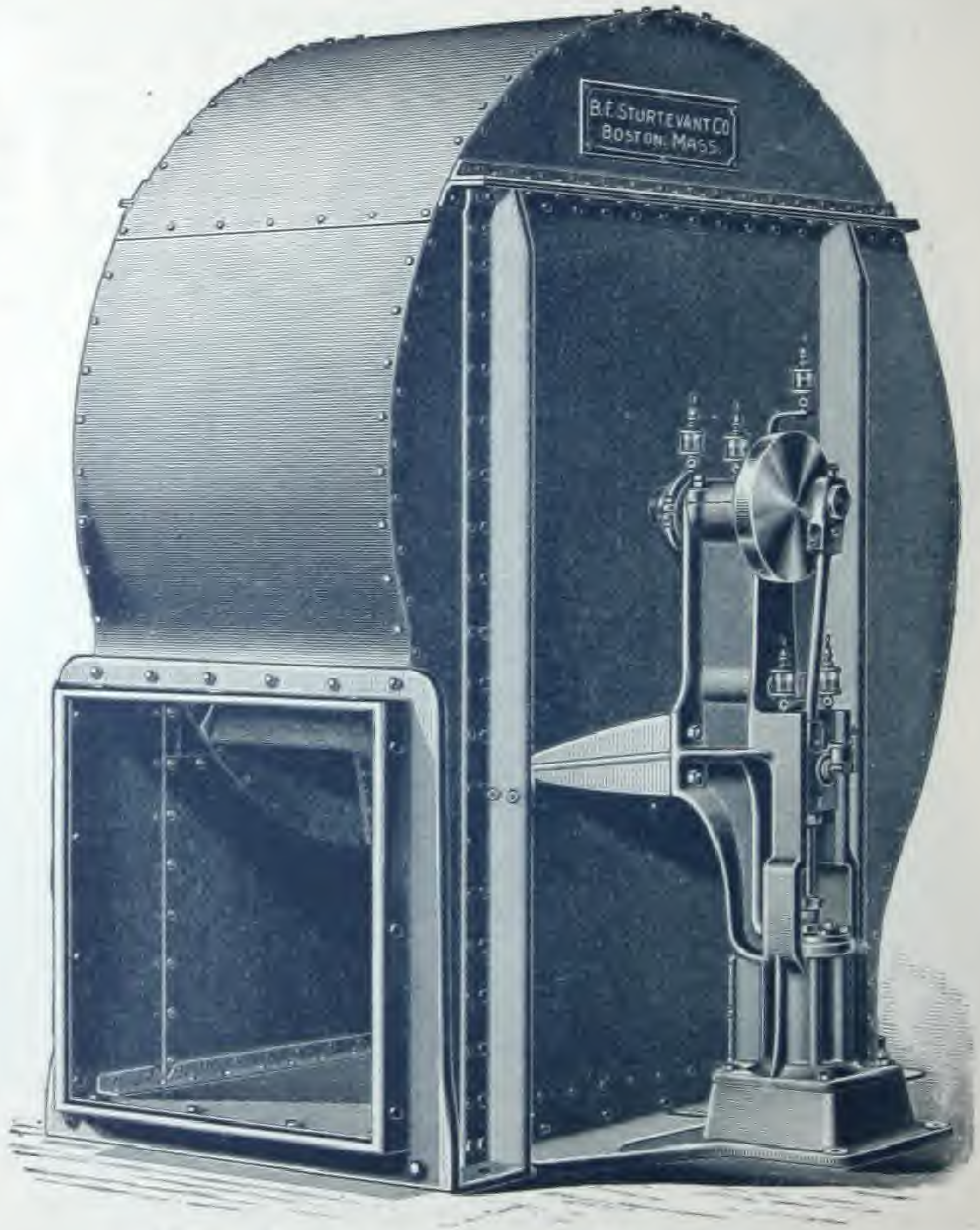



FIG. 25. STEEL PLATE STEAM FAN.
STANDARD TYPE.

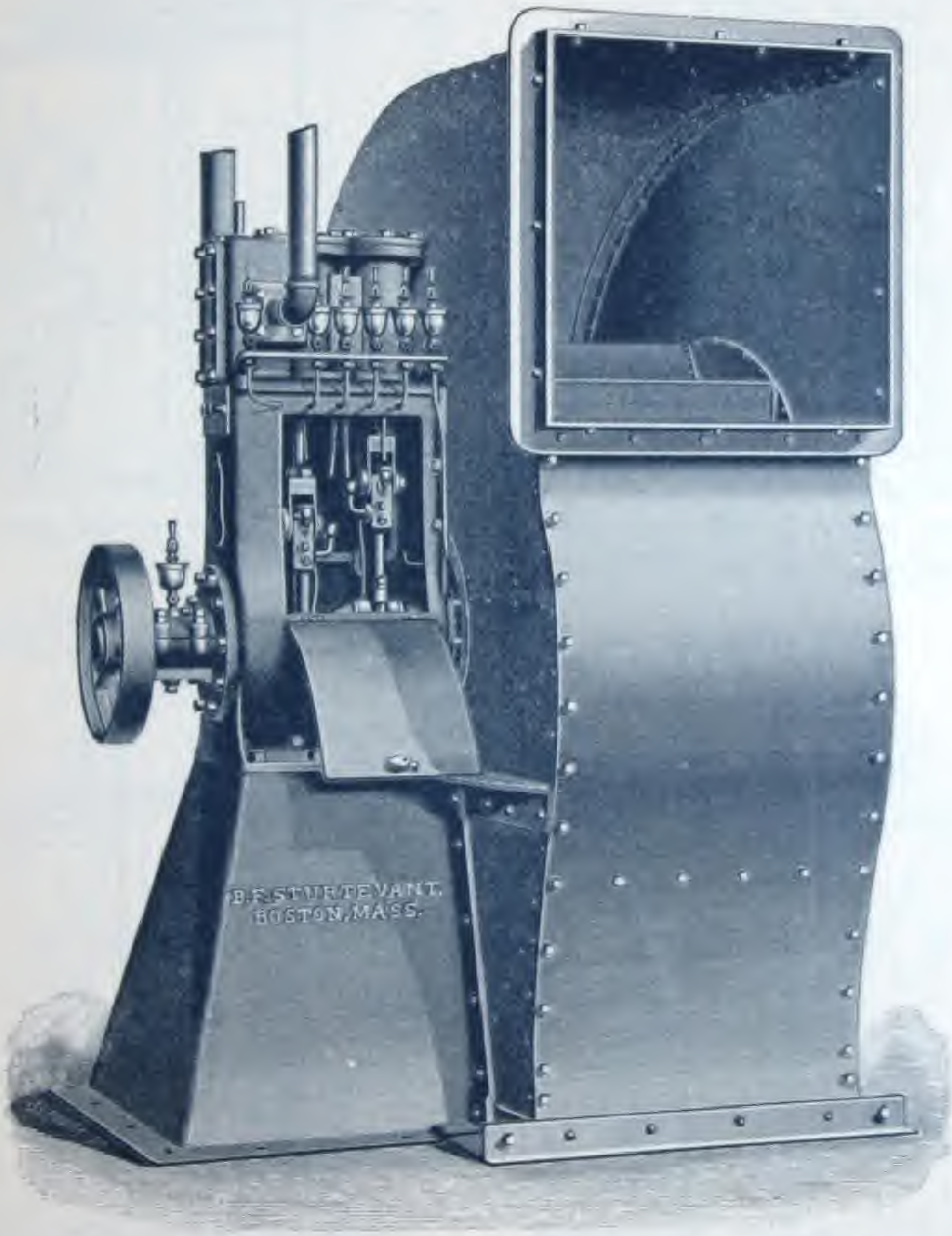



FIG. 26. SPECIAL STEEL PLATE STEAM FAN,
WITH DOUBLE ENCLOSED ENGINE.

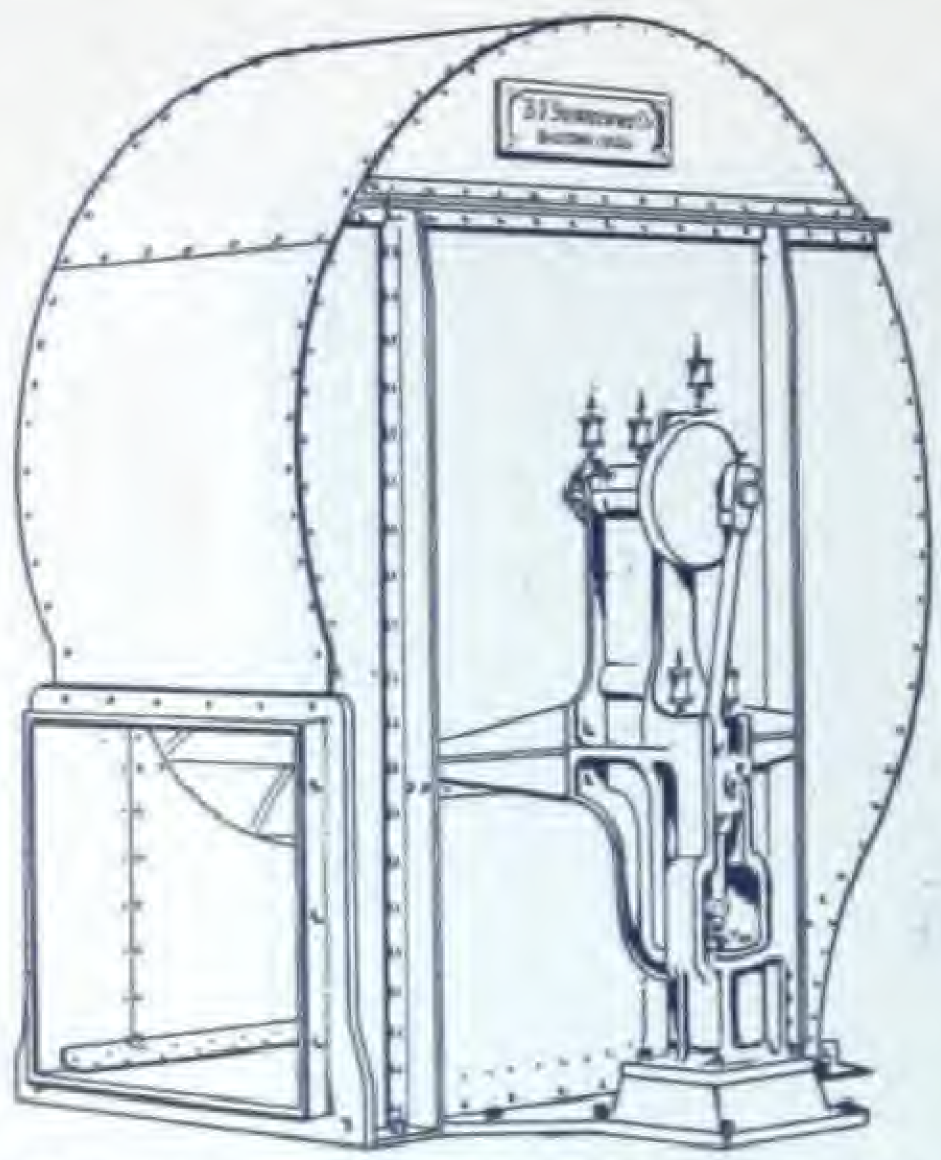


FIG. 27. BOTTOM HORIZONTAL DISCHARGE, RIGHT HAND.

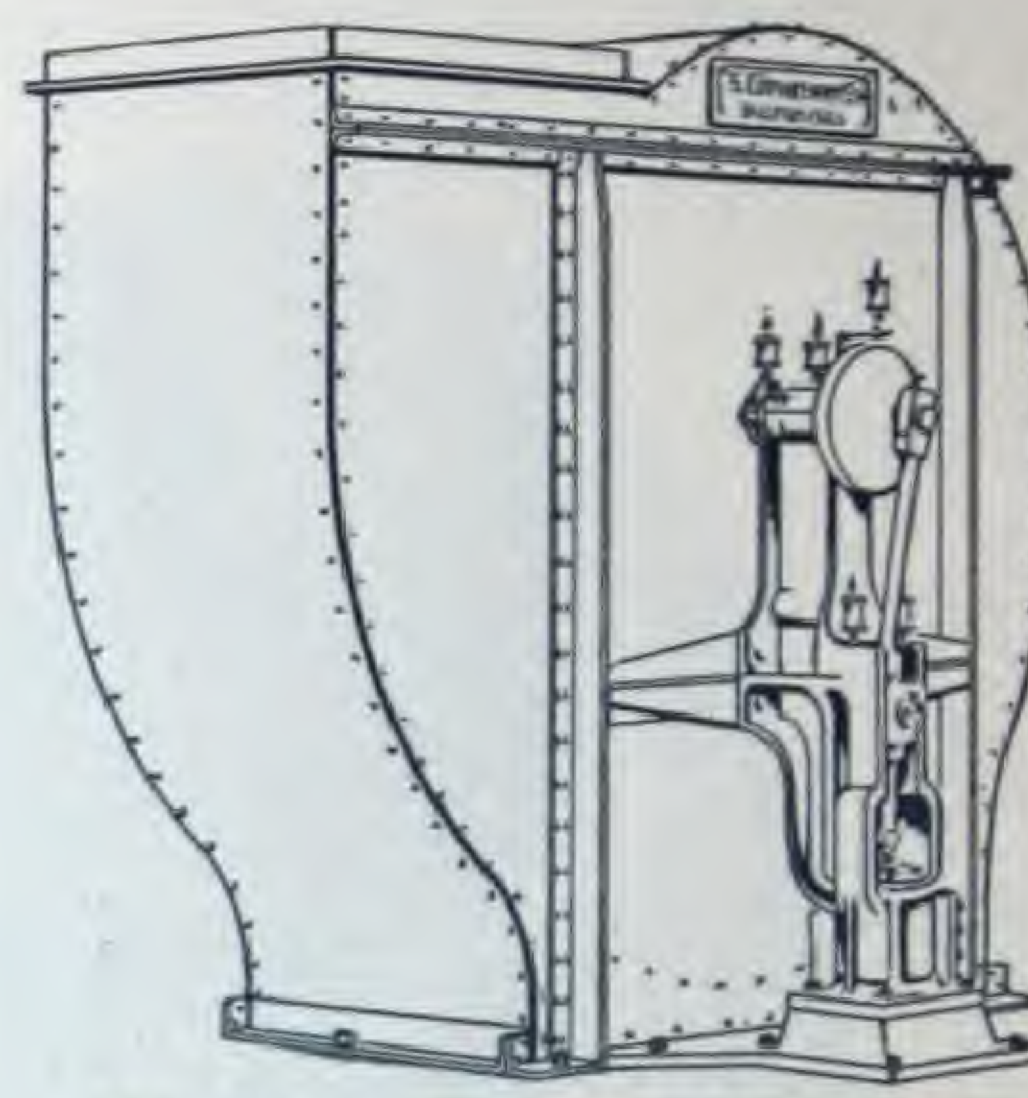


FIG. 28. UP BLAST DISCHARGE, RIGHT HAND.

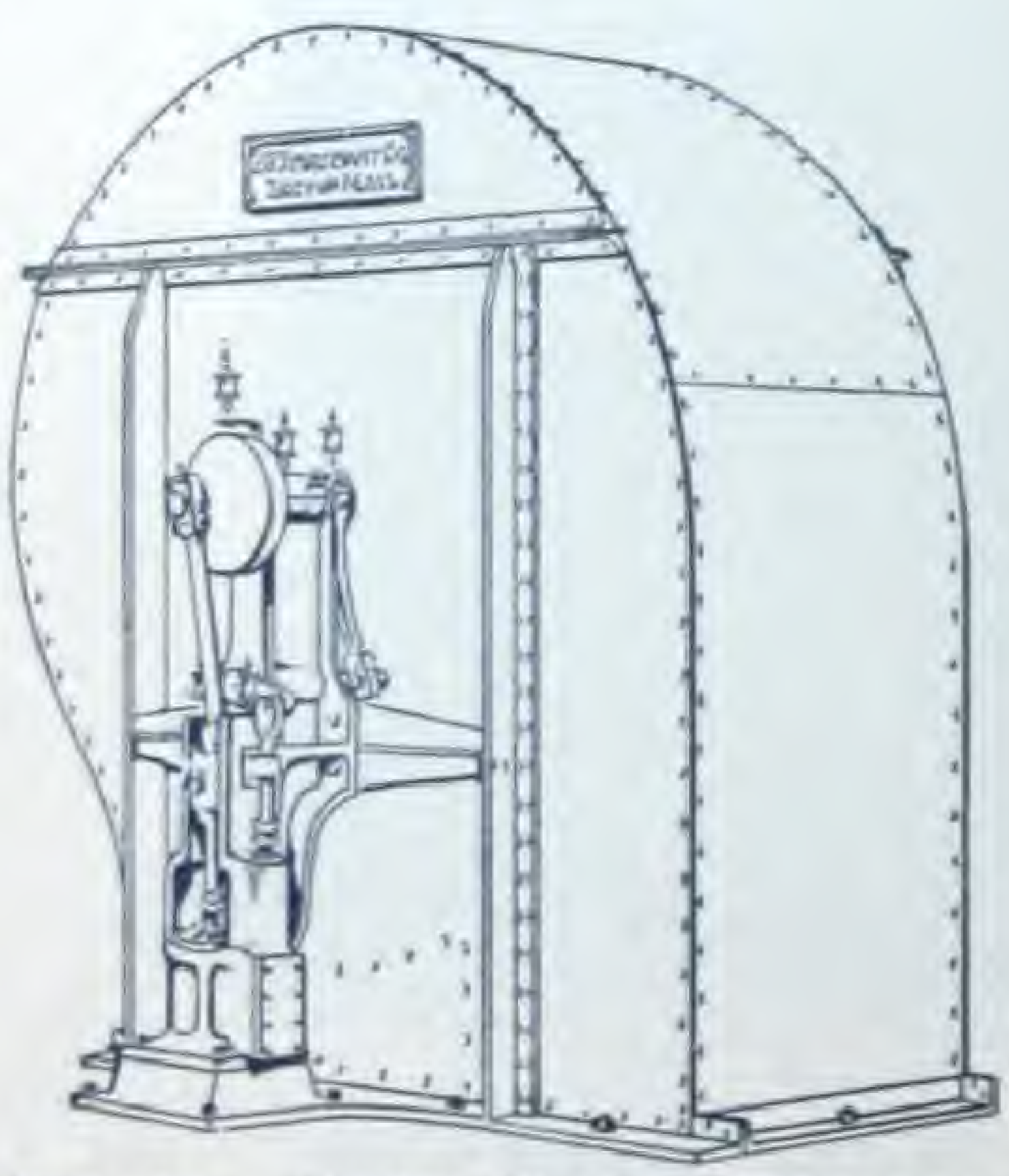


FIG. 29. DOWN BLAST DISCHARGE, LEFT HAND.

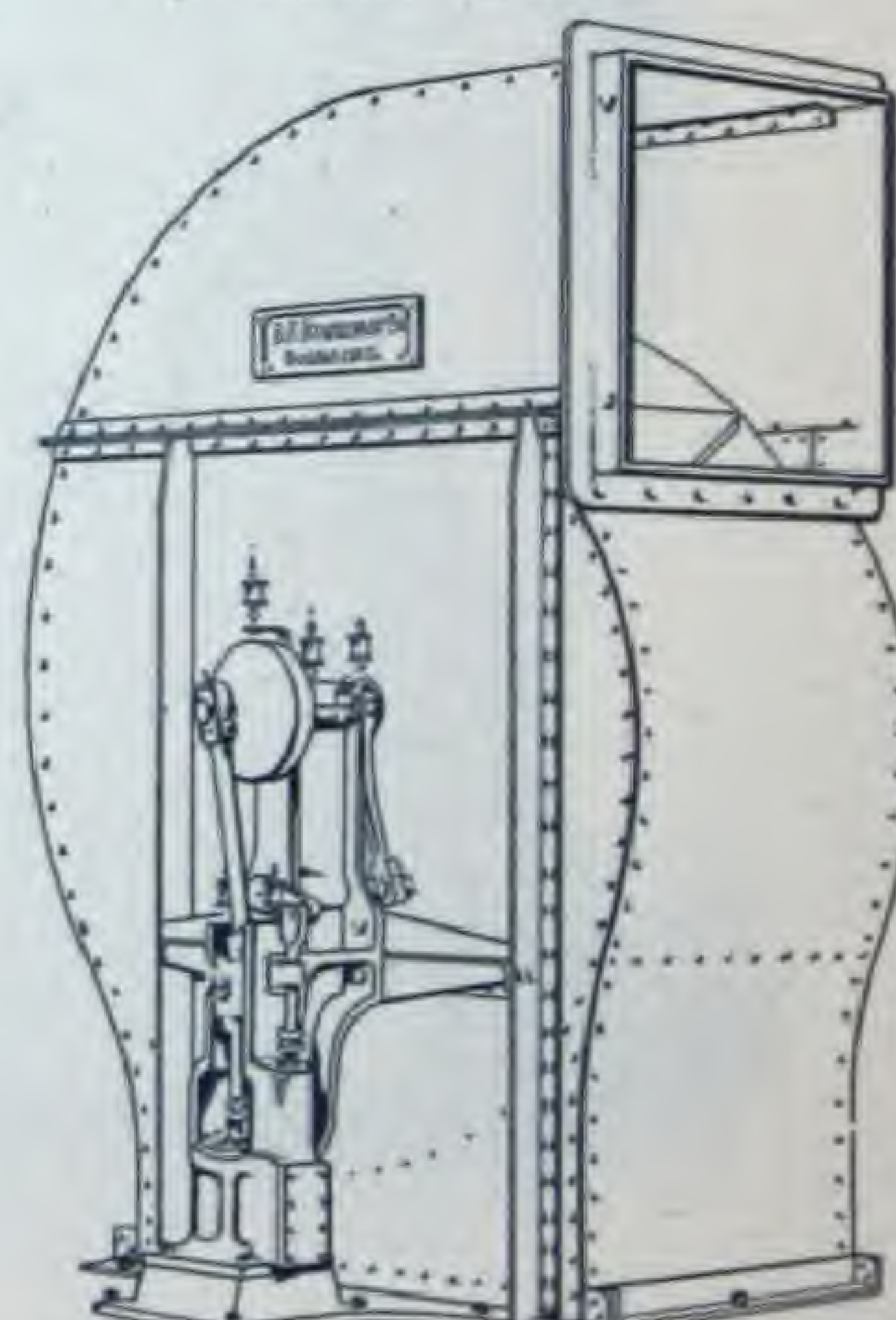


FIG. 30. TOP HORIZONTAL DISCHARGE, LEFT HAND.

FULL HOUSING STEEL PLATE STEAM FANS.

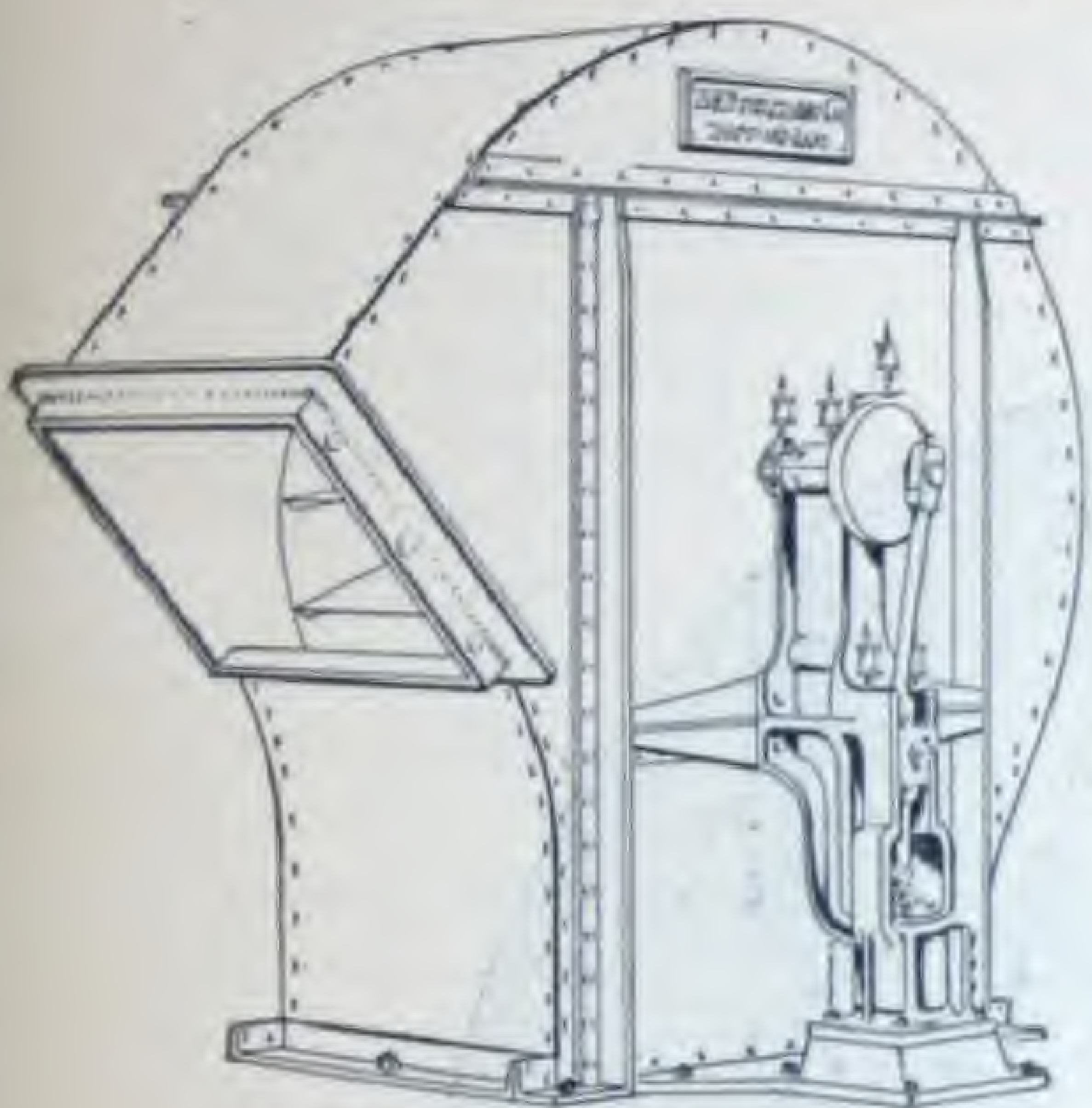


FIG. 31. TOP ANGULAR DOWN DISCHARGE, RIGHT HAND.

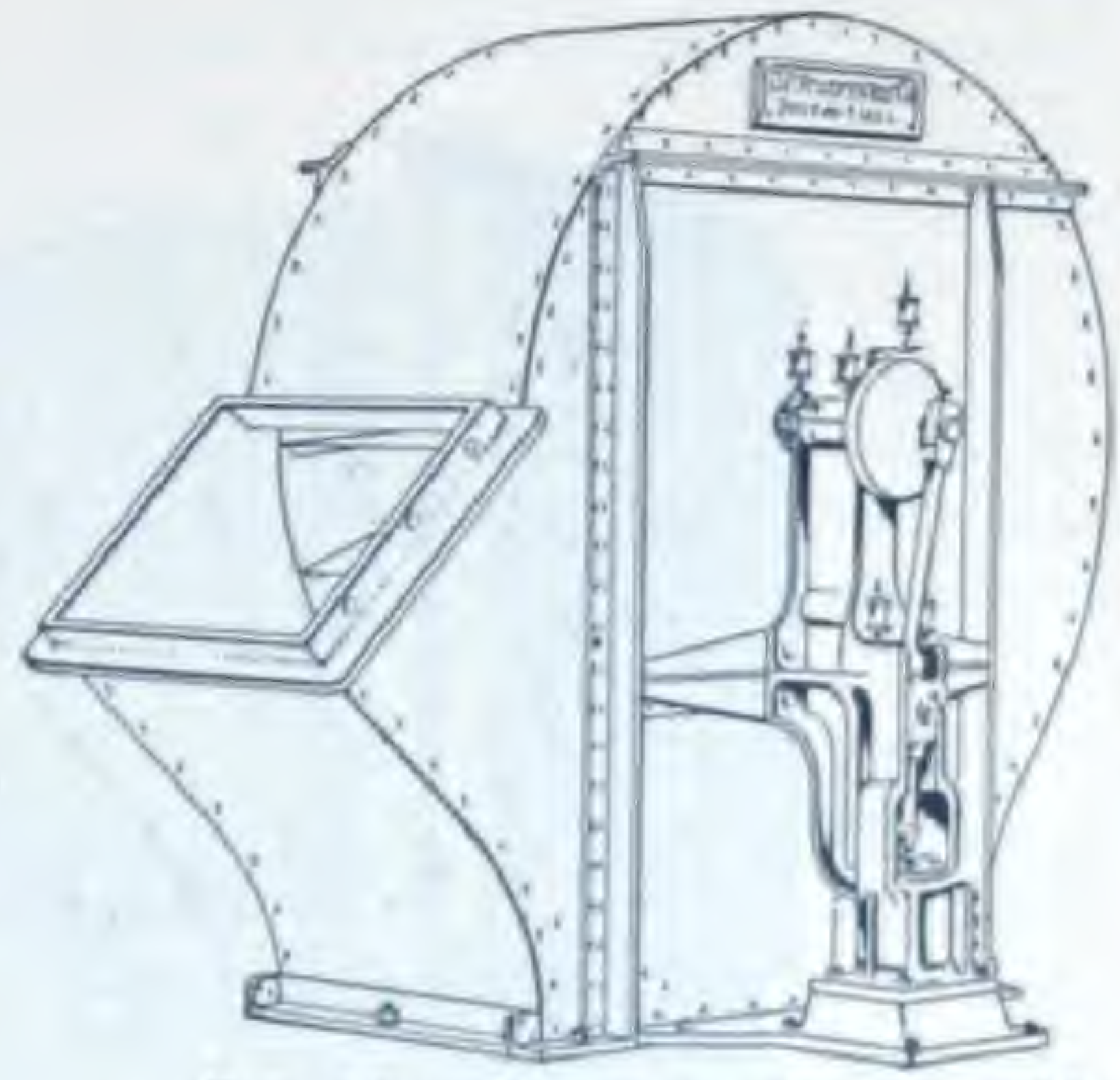


FIG. 32. BOTTOM ANGULAR UP DISCHARGE, RIGHT HAND.

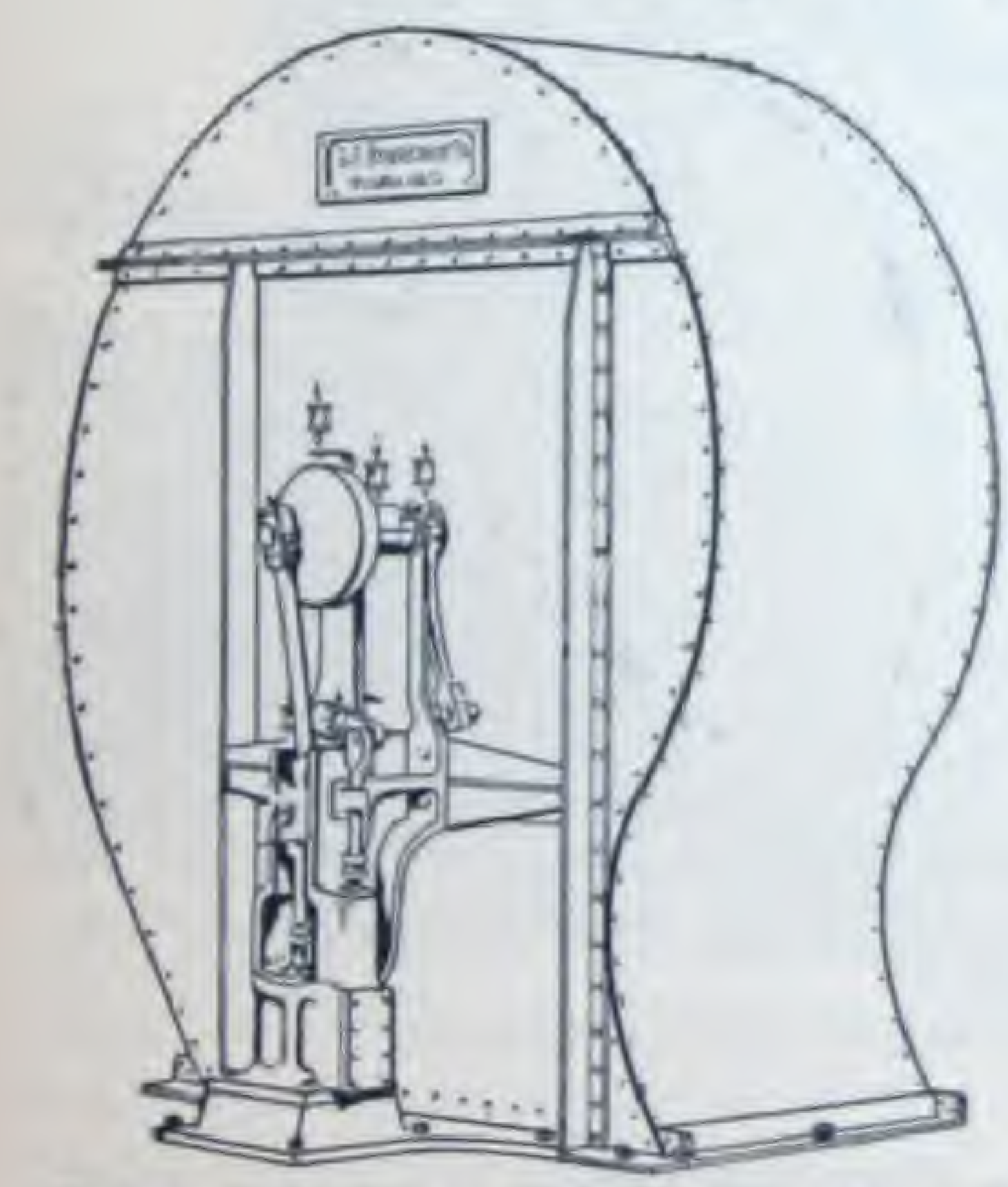


FIG. 33. BOTTOM ANGULAR DOWN DISCHARGE, LEFT HAND.

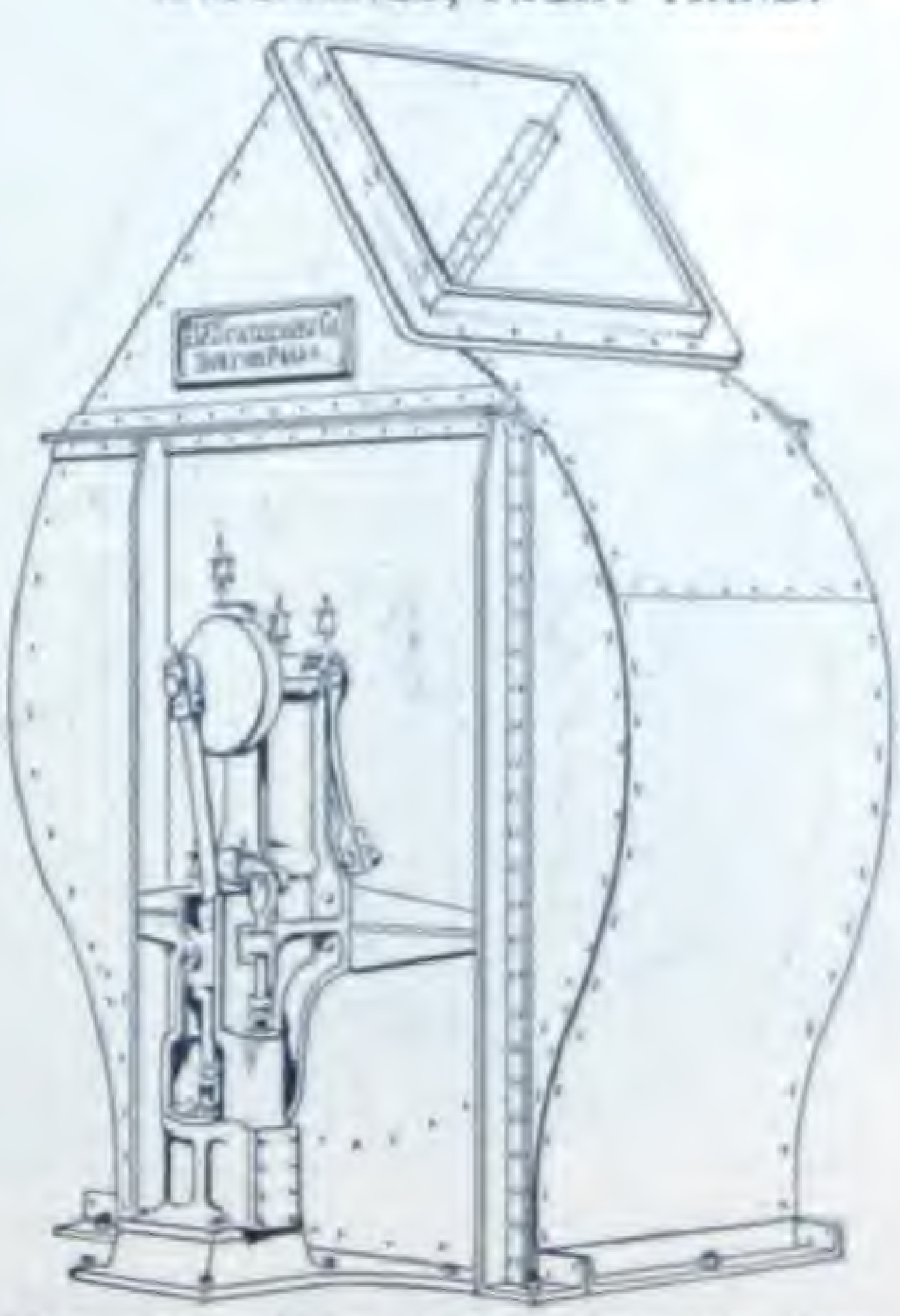


FIG. 34. TOP ANGULAR UP DISCHARGE, LEFT HAND.

FULL HOUSING STEEL PLATE STEAM FANS.

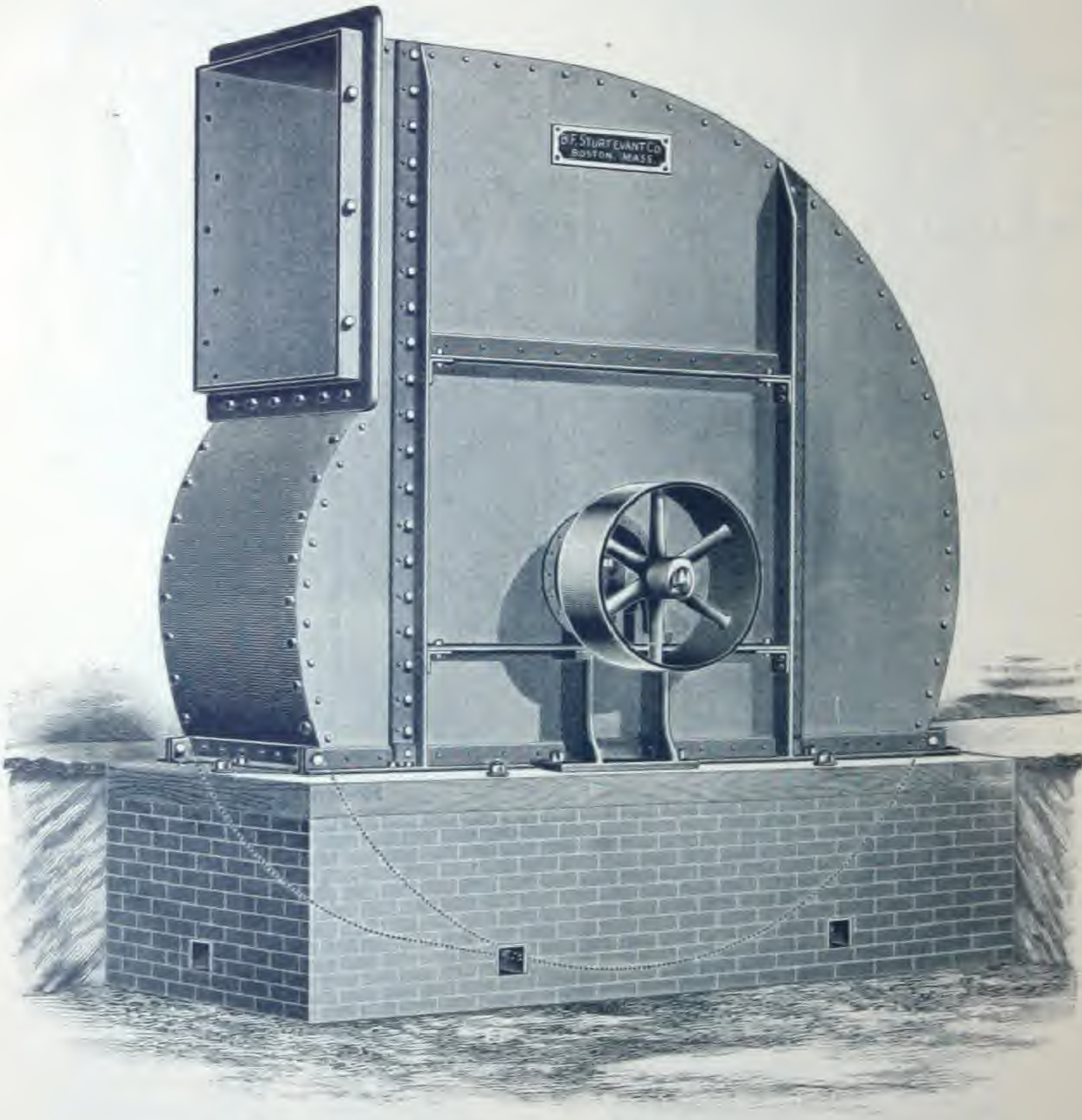



FIG. 35. STEEL PLATE PULLEY FAN,
WITH THREE-QUARTER HOUSING.

THREE-QUARTER HOUSING FAN. In the case of large, full housing fans, their height frequently becomes a serious obstacle to their introduction. As a means of overcoming this difficulty, fans are, therefore, constructed so that the lower portion of their scroll is formed of brick, which, with its side walls, serves at the same time as a substantial foundation. The general idea of such construction in the case of a top horizontal three-quarter housing pulley fan is presented in Fig. 35. Here the bottom part of the space within the enclosing walls of the foundation is cemented over to correspond to the curve which this portion of the fan scroll would naturally take if the entire structure were of steel plate.

The three-quarter housing is of especial advantage where it is desired to connect with an underground duct through which the air is to be forced. The fan then sets directly over the end of the duct, as in Fig. 36. The duct at its end conforms to a continuance of the curve at the back of the fan. The cut shows a steam fan in which, as is customary, the engine is of the horizontal type. The long cast-iron base of this engine, attached to the substantial brick foundation, furnishes an exceptionally solid support, and renders the entire construction perfectly rigid. The engine proper is identical in construction with the regular independent engines of the same form, is provided with adjustment for all moving parts, is completely equipped with oiling devices, and thoroughly built for continuous operation.

The utility of such a design must be evident; in fact, this is the accepted form for introduction in the case of almost all plants of large size. The underground brick duct permits of the distribution of air to the vertical flues without encroaching on available floor space or head room.

The three-quarter housing fans are constructed in the same standard forms of discharge as are the full housing fans illustrated in Figs. 27 to 34 inclusive. From this large assortment may be readily chosen the shape that is best suited to the conditions under which it must be installed. At all events, a fan of this type can be specially constructed to meet almost any conceivable requirements.

The duplex type of three-quarter housing steam fan, illustrated in connection with a heater upon a succeeding page, is frequently of great convenience. Each fan is provided with its individual engine, and the fans set side by side with their shafts in the same line. The shafts, which are extended until they meet, are rigidly connected by a coupling. Under ordinary conditions both engines are operated; but, if under any circumstances, one of these becomes disabled, they may both be driven at only twenty per cent. less speed by the other engine.

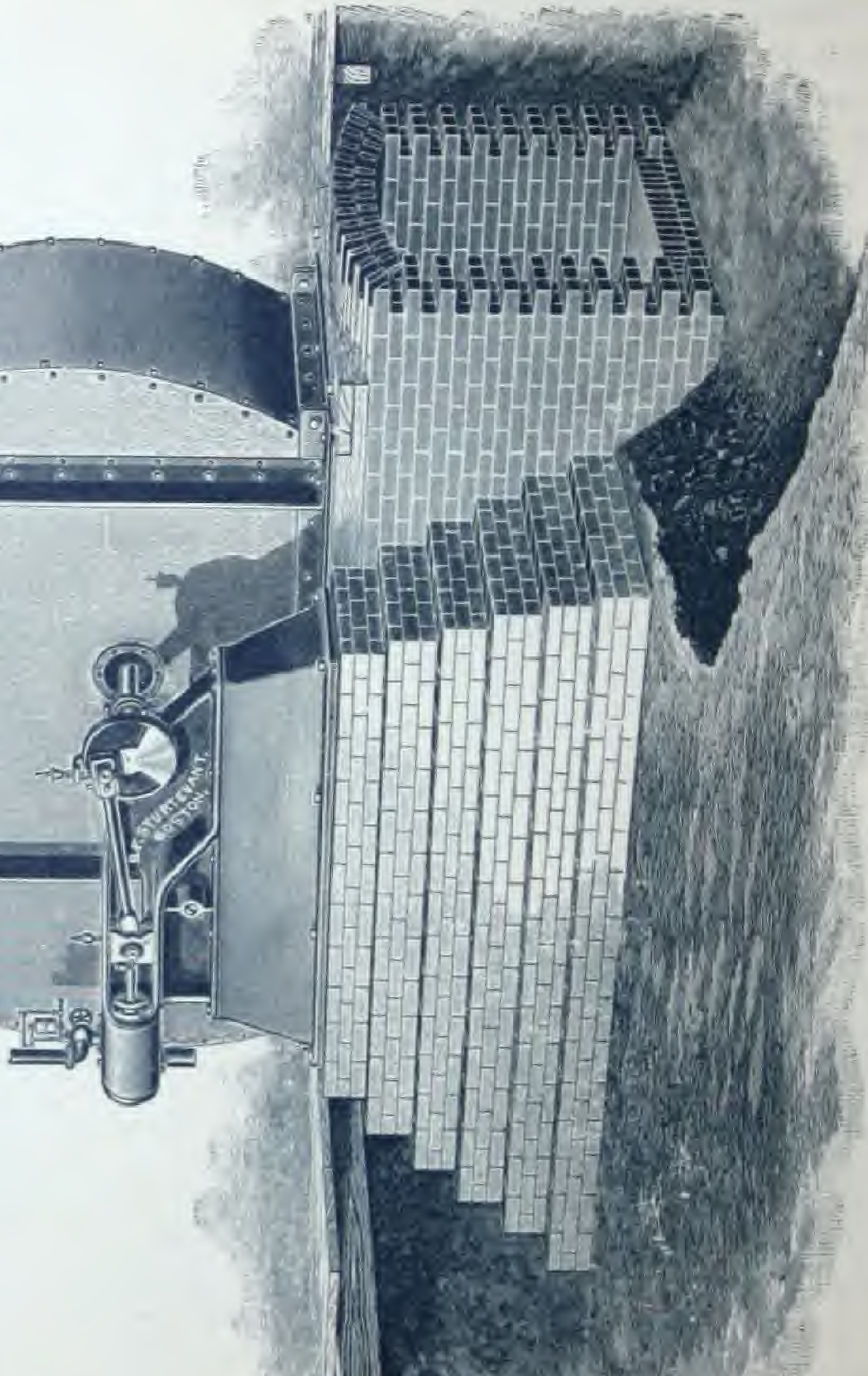



FIG. 36. STEEL PLATE STEAM FAN,
WITH THREE-QUARTER HOUSING.

SINGLE UPRIGHT ENGINE. The most delicate mechanism in any mechanical heating and ventilating plant is usually the motor. It is, therefore, essential above all else that its design and construction should be as near perfection as possible. The engine being the most generally employed means of fan propulsion, has received, at the hands of this Company, the most careful attention. For general independent work, as well as for the driving of fans by belt, these engines are built in a variety of forms, each best suited to its given duty.

The single-cylindered upright engine shown in Fig. 37, as arranged for automatic regulation, is, for heating work, usually provided with a throttling governor. The entire frame is simple, strong and pleasing in outline.

The valve is of the balanced-piston type and receives its motion through a rocker, from a single eccentric, which is so pivoted to the governor wheel that a change in the position of the governor weight causes it to swing across the shaft. This movement changes the travel of the valve and regulates the points of cut-off and compression. The governor wheel, which is exceedingly heavy, is designed for a balance wheel, but may be utilized as a band wheel. The opposite end of the shaft is splined to receive an additional wheel.

The cylinders are thoroughly lagged. The crank pin is oiled from a stationary sight-feed oiler, and all other oil cups, except that on the cross-head, are stationary and feed moving parts by dropping the oil into catch cups.

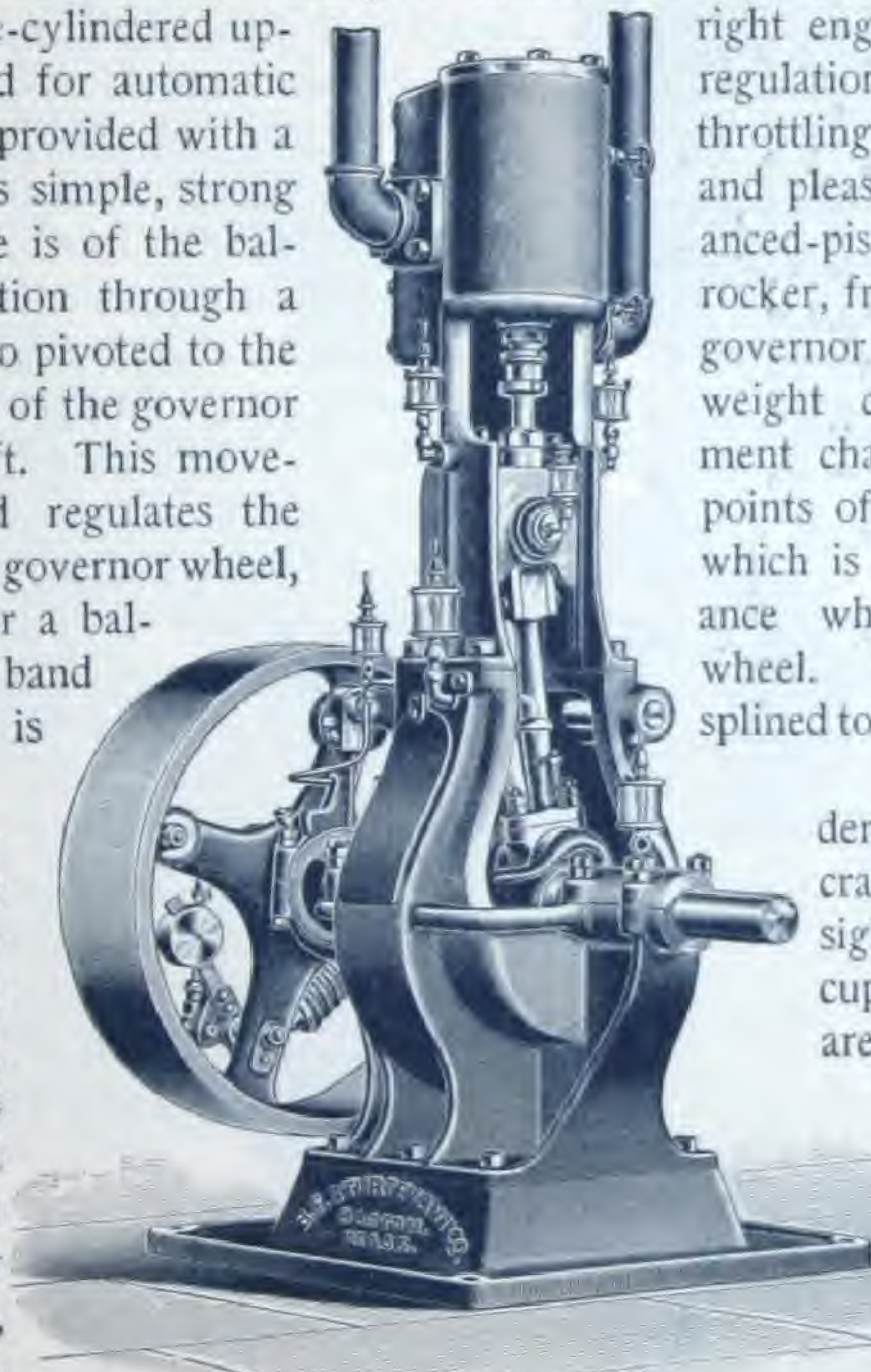


FIG 37. SINGLE UPRIGHT ENGINE.

Although these engines are regularly constructed for high pressure, they are also furnished in a full line of sizes with large cylinders designed to be operated at pressures of 40 lbs. and under, which are usually prevalent in heating plants. A small engine of great power can thus be furnished at a comparatively low price.

DOUBLE UPRIGHT ENCLOSED ENGINE. Where perfection in operation, the possibility of high speed without noise, or the complete exclusion of dust from the running parts, is desired, the type of engine represented in Fig. 38 may be adopted. The cylinders are placed side by side in the same casting; the cranks are set opposite; the reciprocating parts are balanced in their movements and high speed is made possible. The cylinders are of large diameter as compared with the stroke, so that great power may be developed at high rotative but moderate piston speed.

The steam admission to both cylinders is regulated by a single piston valve, under the control of a shaft governor of the same design as that used upon the single upright engines. All moving parts subject to friction are of steel and the bearings of ample size. Automatic relief valves are provided to prevent any danger of damage by water in the cylinder. Complete sight-feed oiling arrangements from a single oil tank connect with all of the bearings and the frame is so constructed as to entirely enclose all running parts, while still leaving them accessible by merely opening the door. A throttling governor is usually employed when the engine is used in connection with a heating plant.

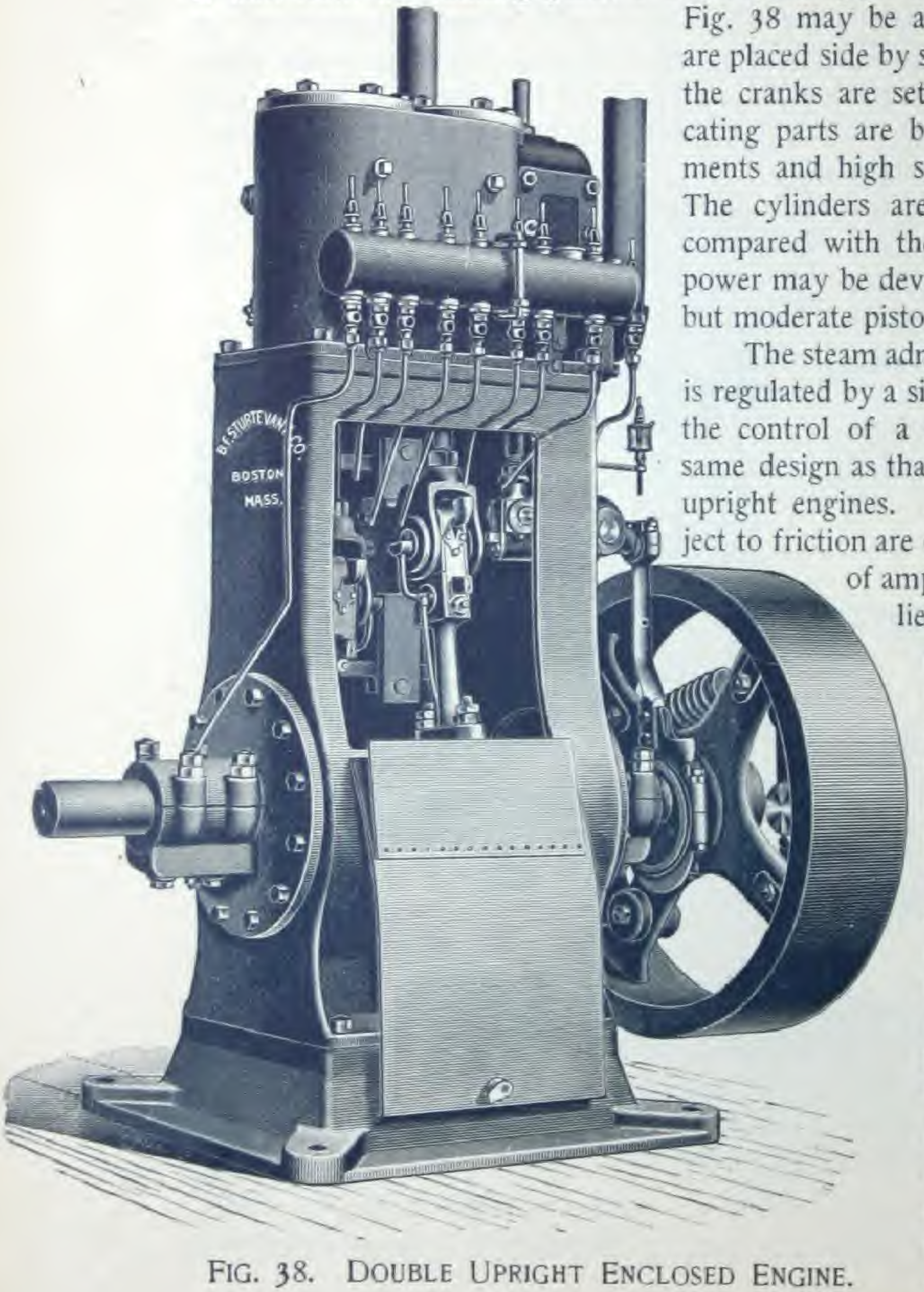


FIG. 38. DOUBLE UPRIGHT ENCLOSED ENGINE.

HORIZONTAL ENGINE. The engine illustrated in Fig. 39, as will be noted, is provided with an extremely large cylinder and is specially designed for use in connection with heating plants. It is here shown with a throttling governor, but is in every way, except in the size of its cylinder, identical with the other Sturtevant engines of this type. Being designed, however, for operation under low steam pressure, it is available for a special line of work for which few engines are distinctly constructed; in fact, the Sturtevant low pressure engines stand practically alone in their class.

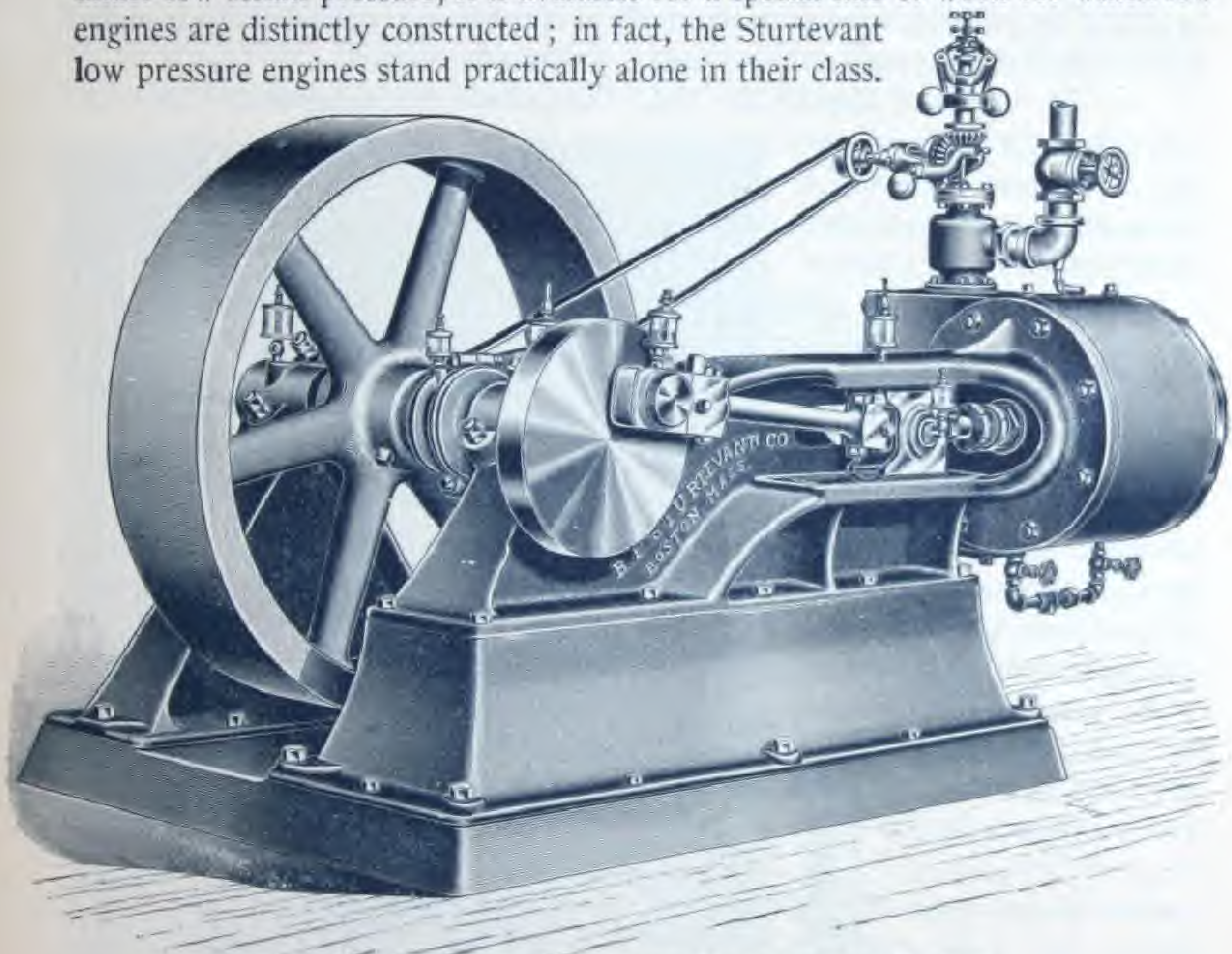


FIG. 39. LOW PRESSURE HORIZONTAL ENGINE.

The engine is built either with a self-contained bed which allows of transportation without disturbance of parts, or with the engine and pedestal independent. As durability is to a great extent dependent upon simplicity, this engine has this marked advantage in its favor, that there are few moving parts subject to wear. All such parts subject to friction are of steel and the bearings of ample size. Special continuous oiling devices are provided, guaranteeing cool bearings and reducing the friction to a minimum.

## HEATERS.

CORRUGATED SECTIONAL BASE HEATER. The heater itself must be compact, efficient, easily operated or repaired, and of such construction as to make a change in its capacity a simple matter. All of these features were carefully considered in the design of the Sturtevant Heater, and the proportions in which the individual heaters are made up for use are regulated by formulas derived from the extensive experiments previously related.

In Fig. 40, is indicated in detail the general construction of the individual sections of a heater. The foundation upon which the heater rests is constructed entirely of steel angles, flanged and bolted. Upon this, and the expansion balls, rests a series of sectional bases, each section containing either two or four rows of vertical pipes, according to the requirements, connected by cross pipes at the top as shown. The length of these pipes and their position prevents the evil effects of the unequal expansion of the pairs of vertical pipes, which in heaters of other makes, frequently have return bends in place of cross pipes. Free expansion lengthwise of the sections is allowed for by resting one end of the sections upon balls, E, Fig. 41, which are supported by a casting beneath.


FIG. 40. CORRUGATED SECTIONAL BASE HEATER.

In order to prevent alternate expansion and contraction of the air between the pipes in the heater, and at the same time economize room and material, the

sides of the sections are corrugated so that they fit each other closely and allow an equidistant spacing of the pipes in the heater. Upon the end of each section is a circular flanged head, divided by a horizontal diaphragm, the upper part communicating with the steam supply, and the lower with the drip. The sides of the heads are surfaced and closely fitted; a blank flange is placed at one end of the series and the large steam inlet and drip header at the other. These heads are tightly drawn together by substantial through bolts, and tight joints are positively secured by the use of special gaskets. The upper parts of all sections thus communicate with the inlet and the lower parts with the drip.

Steam is admitted through the inlet pipe A, passes into the sections, thence up, over and down the pipes, into the separate space in the section, which communicates with the drip, whence it leaves the heater as water of condensation, through the drip pipe B. Every square inch of the heating surface of the pipes and section is thus utilized, and the water is conveyed away through the pipe in the header, in the upper part of which steam is admitted. A small hole in the horizontal diaphragm, near the middle of the section, allows of complete drainage of the water from each section.

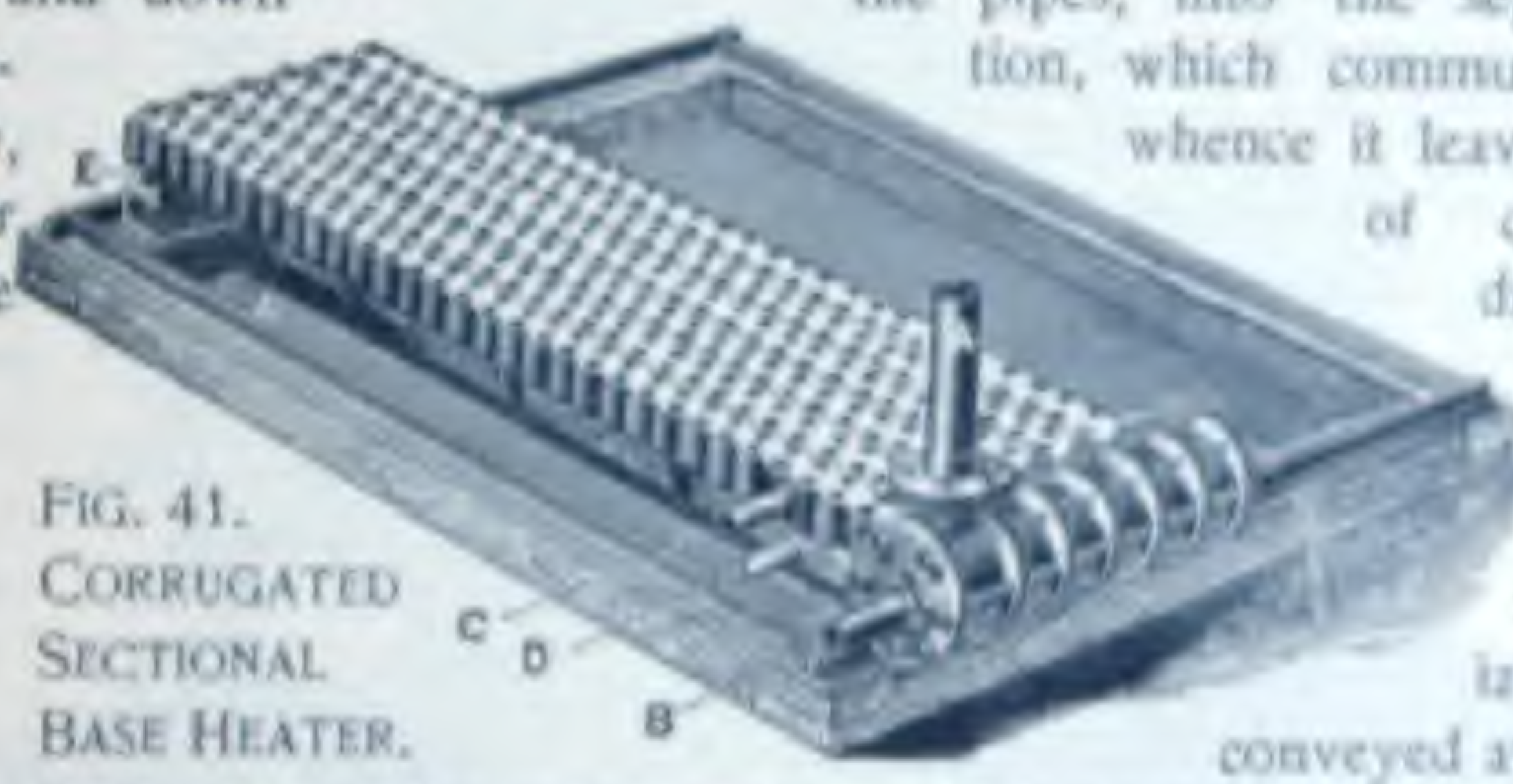



FIG. 41. CORRUGATED SECTIONAL BASE HEATER.

The pipes, C and D, are respectively the exhaust steam inlet and drip for the single independent section provided to utilize the exhaust steam from the fan engine. This section is made without a head and is not in communication with the other sections.

The areas for the inlet and drip are very large and direct, giving an opportunity for the use of exhaust steam without back pressure upon the engine. This arrangement does away with all inlet pipes and manifolds, with their numerous flanges and bolts; there are no connecting nipples, allowing of constant racking by unequal expansion, and above all, the inlet and drip are both at the same end of the section, avoiding the great disadvantage of connecting at the opposite ends of the section. When desired, the sections may be made up in more than one group, so as to use exhaust steam in one portion and live in the other. Every heater is encased in a steel plate jacket, preventing all possibility of fire, and allowing of the securing of lower insurance rates.

STEAM TRAP. The Sturtevant steam trap is especially designed for use in connection with the Sturtevant heaters, although it is equally well fitted to remove the water of condensation from steam heaters or radiators of any construction. Its action will be made clear by Figs. 42 and 43. As seen in the sectional view, the body of the trap contains a pot, which, as the water flows from the inlet upon the left into the space around the pot, rises and closes the connection between the interior and exterior. The water accumulates in this space and gradually overflows into the pot until its buoyancy is overcome and it sinks to the bottom.

By this accumulative action free passage for the water is afforded from the pot up through the vertical hollow extension of the cover and thence through the cored passage in the cover to the outer air. The pressure of the steam upon the surface of the water causes this discharge to be rapid, and it continues until the levity of the pot becomes sufficient to cause it to rise and prevent the passage of water by the seating of the extension against the cone screwed into the bottom of the pot. Both extension and cone are of brass, and are ground to a fit, ensuring a tight joint when in contact.

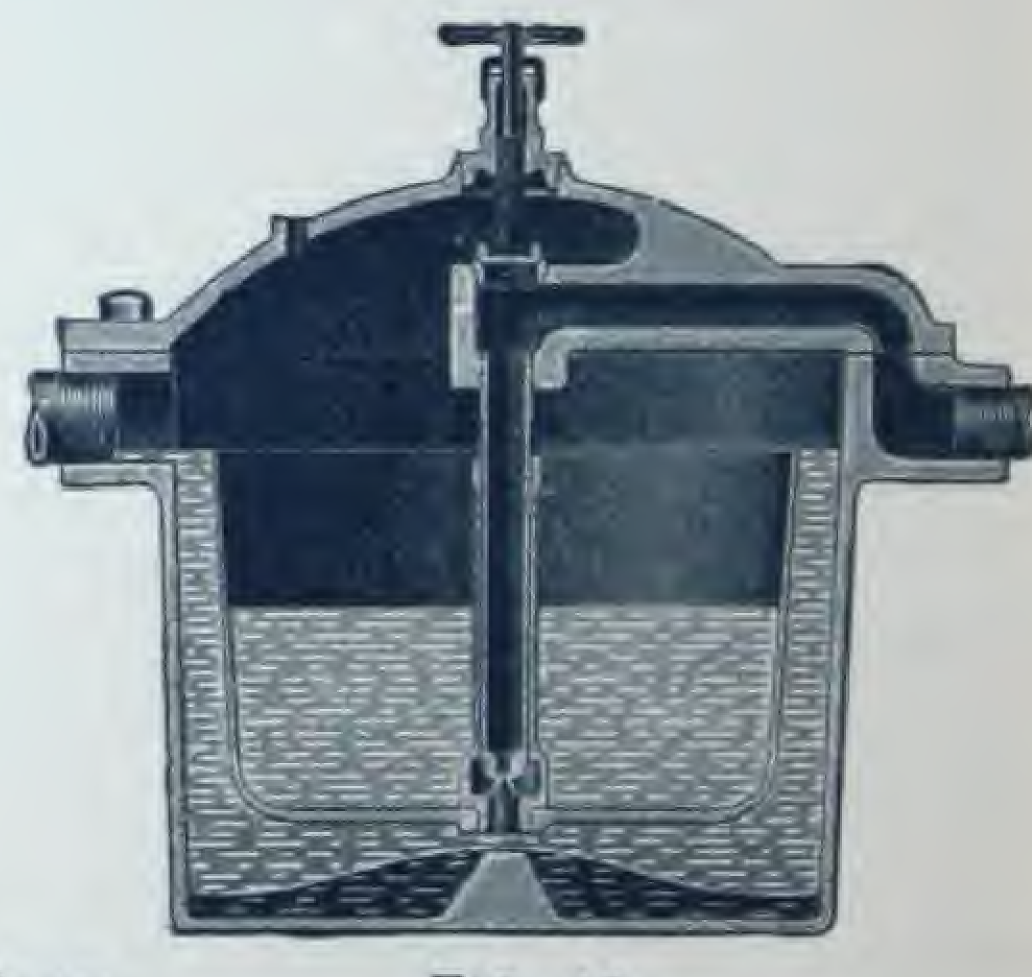


FIG. 42. STEAM TRAP. FIG. 43.

The periodic delivery of water continues as long as there is water to discharge or sufficient steam pressure to cause the trap to act. These traps are specially constructed to act at different steam pressures.

Although certain types of steam traps are designed to return the water of condensation to the boiler, the Sturtevant trap is not intended for this service, but merely to permit of the removal of water from the heater without the escape of steam.

AUTOMATIC RETURN WATER APPARATUS. Economy demands that in any heating plant the water of condensation from the steam should be returned to the boiler. With a simple gravity system or with a hot blast apparatus placed sufficiently above the water level of the boilers, the matter of return of water is simple. But the ordinary plant for the Blower System is placed upon the floor, generally well below the level of the boilers. Some positive and additional means is therefore necessary to lift the water and force it into the boiler against the existing steam pressure.

For this purpose in plants of any reasonable size a steam pump is employed. The water escaping from the heater is first discharged into a tank, which is provided with a float valve, by the action of which steam is admitted to the pump when the water reaches a certain level within the tank. The pump thus set in motion operates until the water has been reduced to such a level that the float again acts, but this time closes the steam admission to the pump. The usual form of the combination of pump and receiver is shown in Fig. 44. The latter is so placed with relation to the pump as to permit of the natural flow of water thereto. A gauge glass on the end of the receiver indicates the water level within. The pump is of the duplex pattern, always to be chosen for this class of work as it ensures more steady running and is far less liable to stoppage than a single-piston pump.

FIG. 44. AUTOMATIC RETURN WATER APPARATUS.

When water of condensation is to be discharged into the receiver from several sources, as from direct radiators in the building and from a regular hot blast heater at the same time, it is necessary that traps be interposed, otherwise unequal condensation in different groups or coils will tend to a backing up of water in those in which the condensation is most rapid, and hence the pressure is least. With exhaust steam discharged directly into the receiver a trap is positively necessary in the connections from other coils using live steam and discharging into the same receiver.

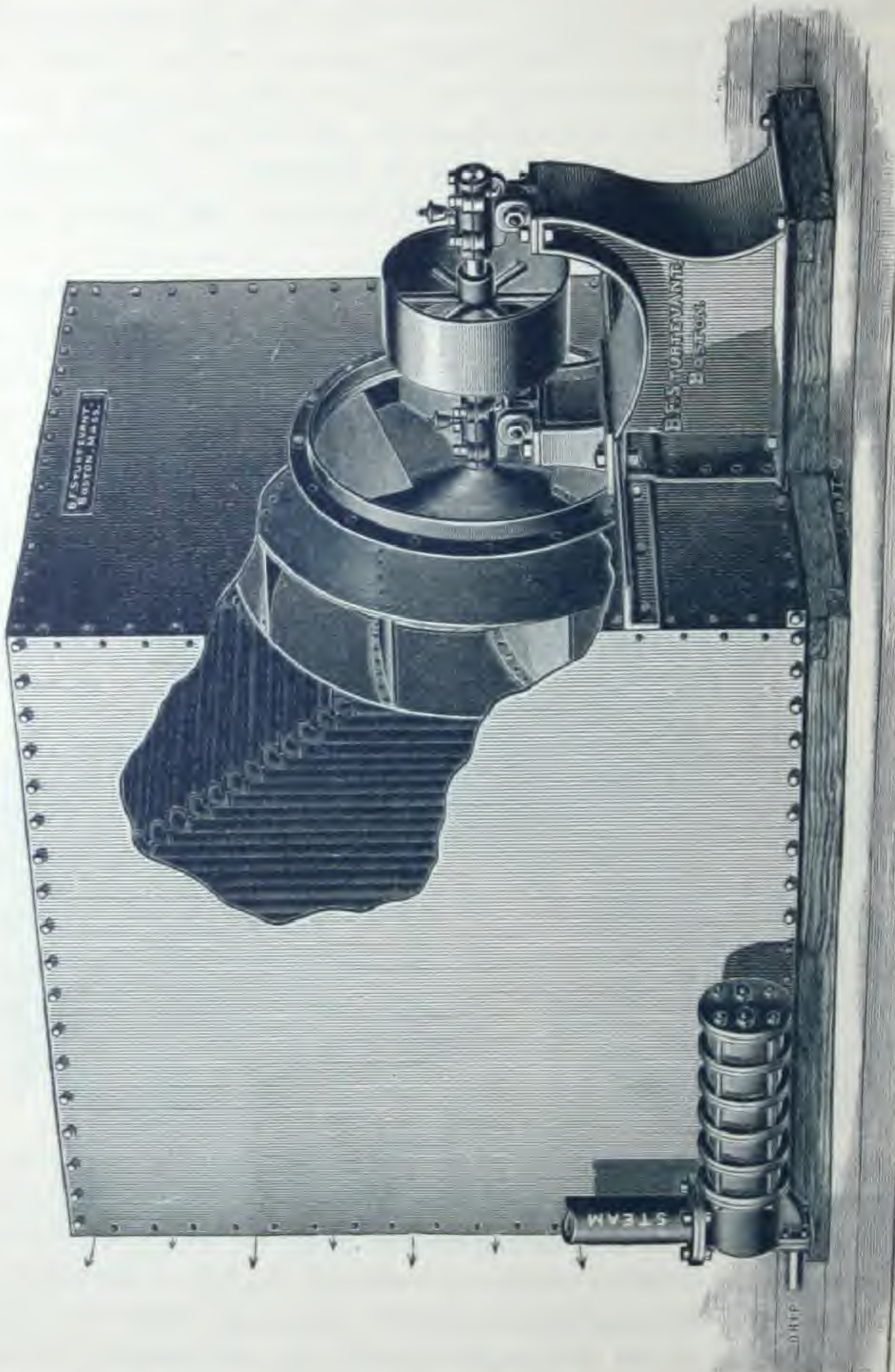



FIG. 45. COMBINED CONE FAN AND HEATER.

# HEATING AND VENTILATING APPARATUS.

COMBINED CONE FAN AND HEATER. The simplest apparatus consists of a cone fan enclosed within the heater case, as shown in Fig. 45. By the fan's action air is forced between the pipes of the heater. The opposite end of the heater may be left open or connected by a suitable duct with any given apartment. For such apparatus the cone fan is far more efficient and desirable than the disc or propeller fan, because of its more positive operation against resistance.

MONOGRAM EXHAUSTER AND SOLID BASE HEATER. In the smallest sizes of heating and ventilating apparatus in which a cased fan is used in connection with a heater, the arrangement is as indicated in Fig. 46. The "Monogram" fan has already been described. The type of heater here illustrated is known as the "Solid Base Heater," and is distinguishable from the corrugated sectional base heaters used in connection with the steel plate fans by the fact that only a single casting is used for each entire heater. The steam supply pipe for these heaters enters the base at the bottom on one side, and the water of condensation escapes from the bottom on the opposite side. A diaphragm in the base compels the steam to flow through all the pipes, thus util-

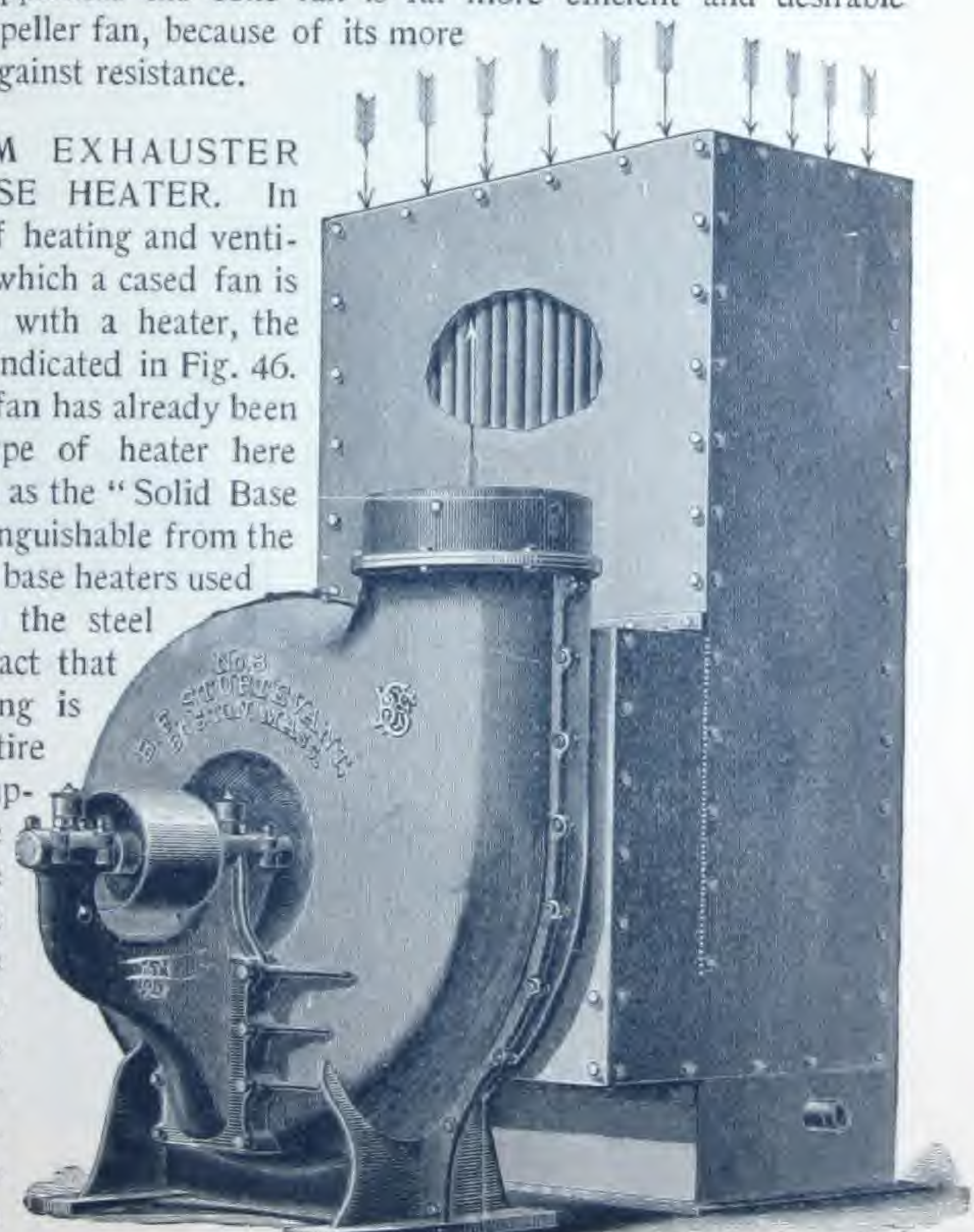


FIG. 46. MONOGRAM EXHAUSTER AND SOLID BASE HEATER.

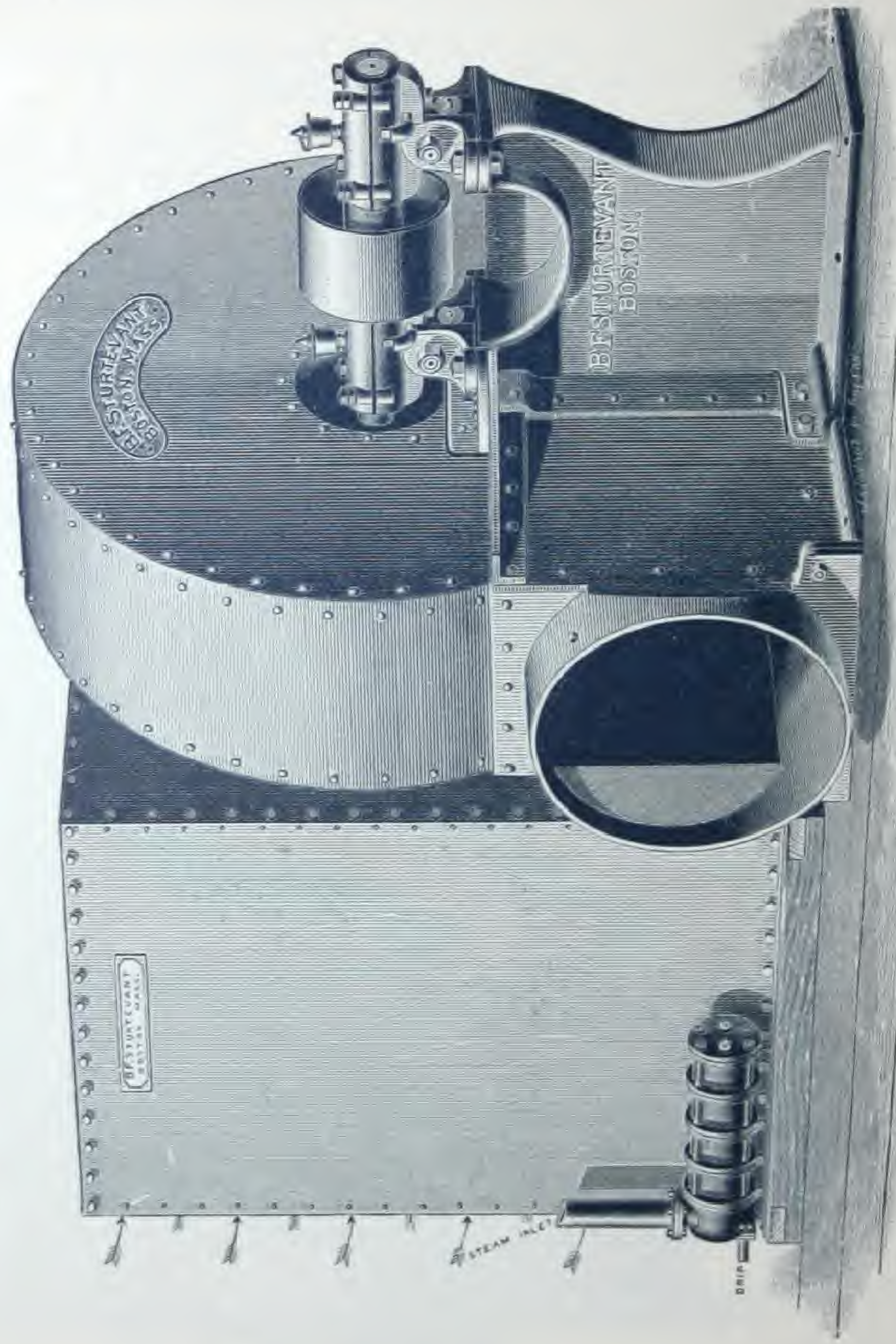



FIG. 47. STEEL PLATE EXHAUSTER,
WITH OVERHUNG WHEEL AND CORRUGATED SECTIONAL BASE HEATER.

izing all the heating surface. The pipes are of steel, and the heater entirely encased in steel plate, with a receiving chamber for the air where it enters the fan. Ordinarily the air is taken in at the top, either from the room or through a pipe connecting with the desired fresh air supply. The air discharged from the fan can be conveyed to any point by means of distributing pipe. All these heaters are designed to use either live or exhaust steam.

HEATING AND VENTILATING APPARATUS WITH PULLEY FAN. The ordinary installation of the Blower System requires an apparatus of larger capacity than can be conveniently constructed of the type just described. To suit all requirements, it is necessary that the construction of the heater should be such as to permit of the most extended range in its sizes, while the fan must be of a type in which the largest capacity may be secured when desired.

In its simplest form, such an apparatus is presented in Fig. 47. The fan is of the steel plate pattern, driven by belt, and constructed as already described. In the larger sizes of pulley fans the "hanger" is omitted, the wheel is not overhung, and the shaft is supported by a box on each side of the shell, as in Fig. 21. The heater here consists of four independent corrugated sections of four rows of pipes each, of the type shown in Figs. 46 and 47. The air passing through the heater is, therefore, brought in contact with sixteen rows of pipe. As these pipes are set staggering, and by means of the corrugations, the sections are allowed to interlock each other, the currents of air are broken up completely and the highest efficiency secured. Obviously, more or less sections could be provided, and they could be separated by a blank flange in such a manner as to permit of using live steam in one of the groups thus formed and exhaust steam in the other. The lower pressure steam coils are always so located as to be first presented for contact with the air before it passes across the pipes of the higher pressure group, where its temperature is increased.

The location of the drip is clearly shown. When live steam is used this is connected with a steam trap provided for the purpose, in order to free the heater of water without allowing any escape of steam.

Arranged as here shown, this is known as a "draw-through apparatus," the air first passing through the heater before it enters the fan. The direction of discharge of heated air from the apparatus is, therefore, entirely dependent upon the construction of the fan. Although here shown with a bottom horizontal discharge, it is evident, from preceding descriptions, that fans of this type are regularly made in a large variety of directions of discharge, so that change in direction of the air after once leaving the fan is usually avoided.

STANDARD HEATING AND VENTILATING APPARATUS. As has already been indicated, a steam engine is an almost indispensable requisite to any steam hot blast apparatus of more than moderate size. For compactness nothing can excel the combination of corrugated sectional base heater and steel plate steam fan. In the smallest apparatus, of which the steam fan forms a part, the latter is of the type already illustrated, with vertical engine, having its cylinder above the shaft, and provided with two bearings, one upon either

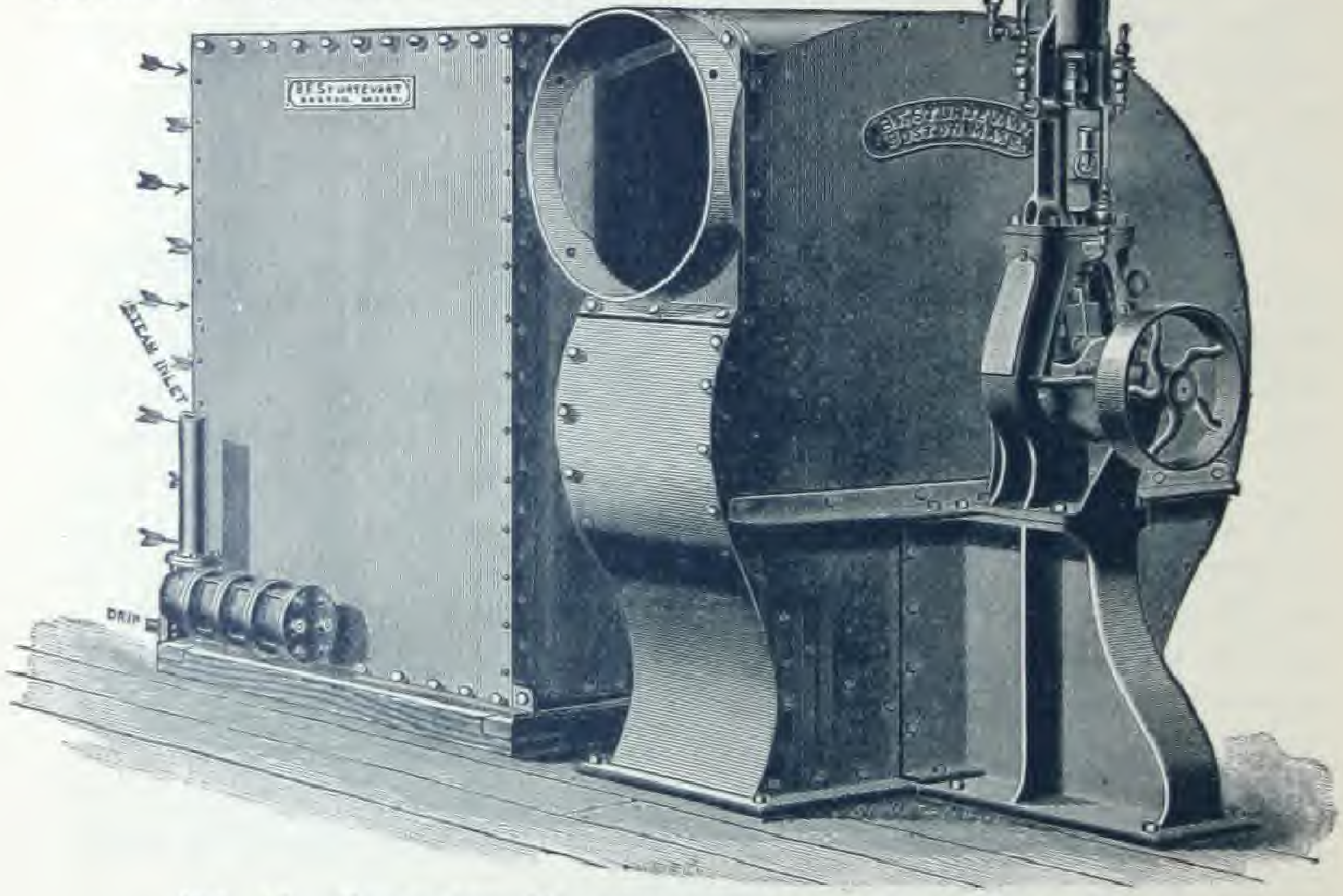



FIG. 48. STANDARD HEATING AND VENTILATING APPARATUS.
SMALL SIZE.

side of the crank, leaving the fan inlet unobstructed. In the apparatus shown in Fig. 48 the fan has a top horizontal discharge.

The heater is constructed on three sections, each having four rows of pipe, all connecting with the same inlet header, and one section of two rows (not seen in cut) provided to utilize the exhaust steam from the fan engine. Either live or exhaust steam may be used in the heater.

Heaters of this size are usually set up on a timber frame, so as to allow of placing the trap upon the floor and connecting the drip directly to it.

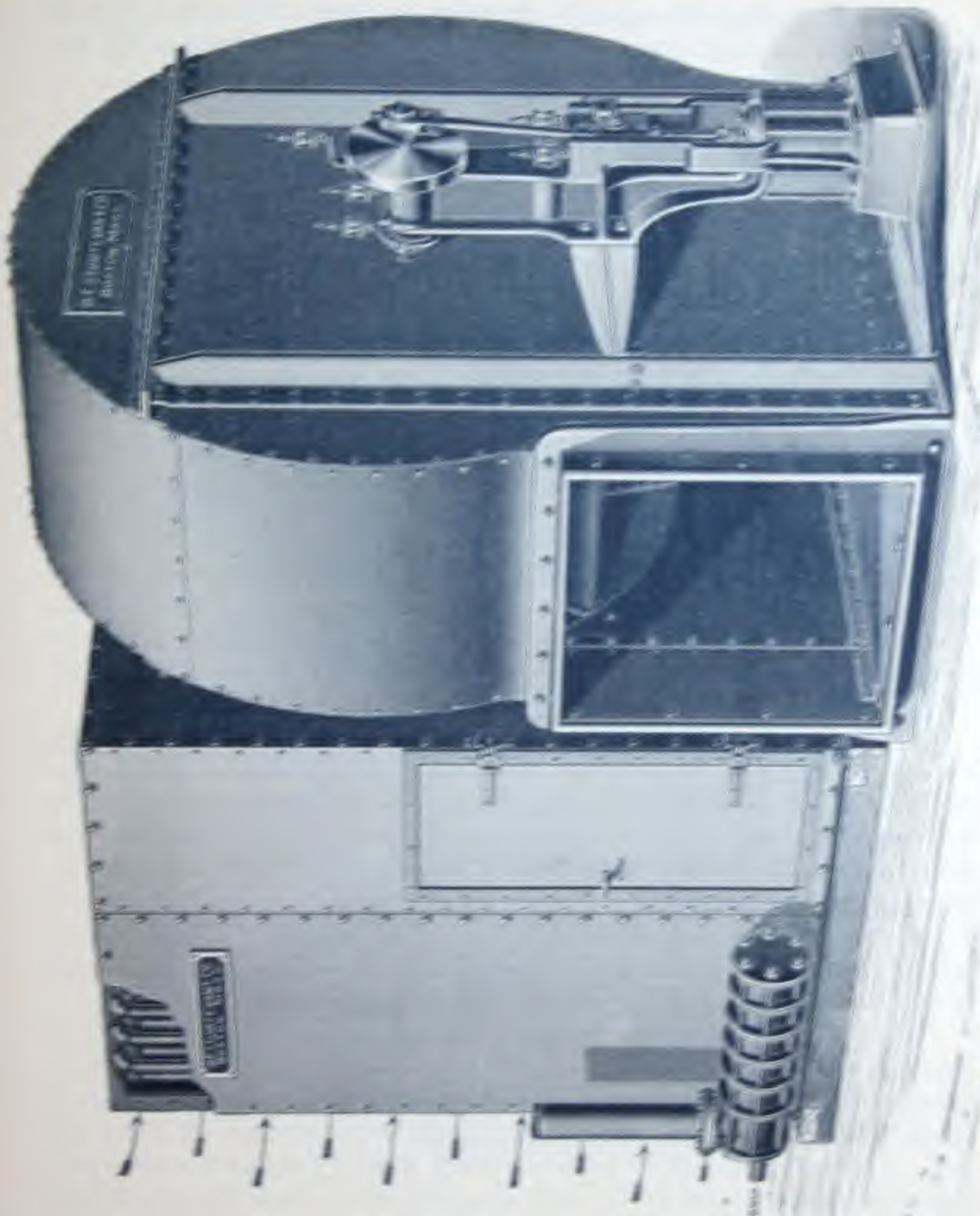


FIG. 49. STANDARD HEATING AND VENTILATING APPARATUS.

In the larger sizes the apparatus maintains its general form, the principal change being in the construction of the steam fan, which, as indicated in Fig. 49, has the engine cylinder beneath the shaft.

BLOW-THROUGH HEATING AND VENTILATING APPARATUS. In the introduction and erection of the Sturtevant steam hot blast apparatus, it frequently happens that the space allotted is of such a shape as to preclude all possibility of placing an apparatus of the ordinary form, arranged to draw the air through the heater before it passes through the fan. If the space is narrow, but of considerable length, it is often a very simple matter to construct the fan to blow the air through the heater, as illustrated in Fig. 50. This makes a narrow, but long, apparatus of equal efficiency with the regular standard apparatus. Such an arrangement is frequently desirable where a pulley fan is to be used in place of a steam fan, and it would be impossible to belt directly to a fan arranged in the regular manner.

The outlet from the heater may be placed in almost any position at the end of the heater, so as to discharge either directly outward at the end, or upward, downward, to the right, or to the left. The discharge of the fan is always made such as to cause the most thorough circulation of the air passing through the heater,— that is, with the discharge at the top of the heater the fan would have a bottom horizontal discharge, while with a bottom discharge on the heater the fan would be top horizontal, as shown in the cut.

The heater shown in the cut consists of four sections, each having four rows of pipes, and all being bolted together in a single group connecting with the same inlet header and drip. Either live or exhaust steam may be used in this portion of the heater; in the former case, the water of condensation is discharged through a steam trap, while in the latter it has a free delivery to the open air, or connects with a return system. In addition to these sections is one more, to utilize the exhaust steam from the fan engine. This section, having no circular head and not projecting through the heater casing, cannot be seen.

The section into which is discharged the fan engine exhaust is always so placed in the heater as to be the first with which the cold air comes in contact, because exhaust steam, having a lower temperature than live steam, would have but little effect in heating air which had already passed through the live steam coil. It is customary in heating and ventilating plants employed in manufacturing establishments to use in the main group the exhaust from the mill or shop engine during the day, and live steam during the night.

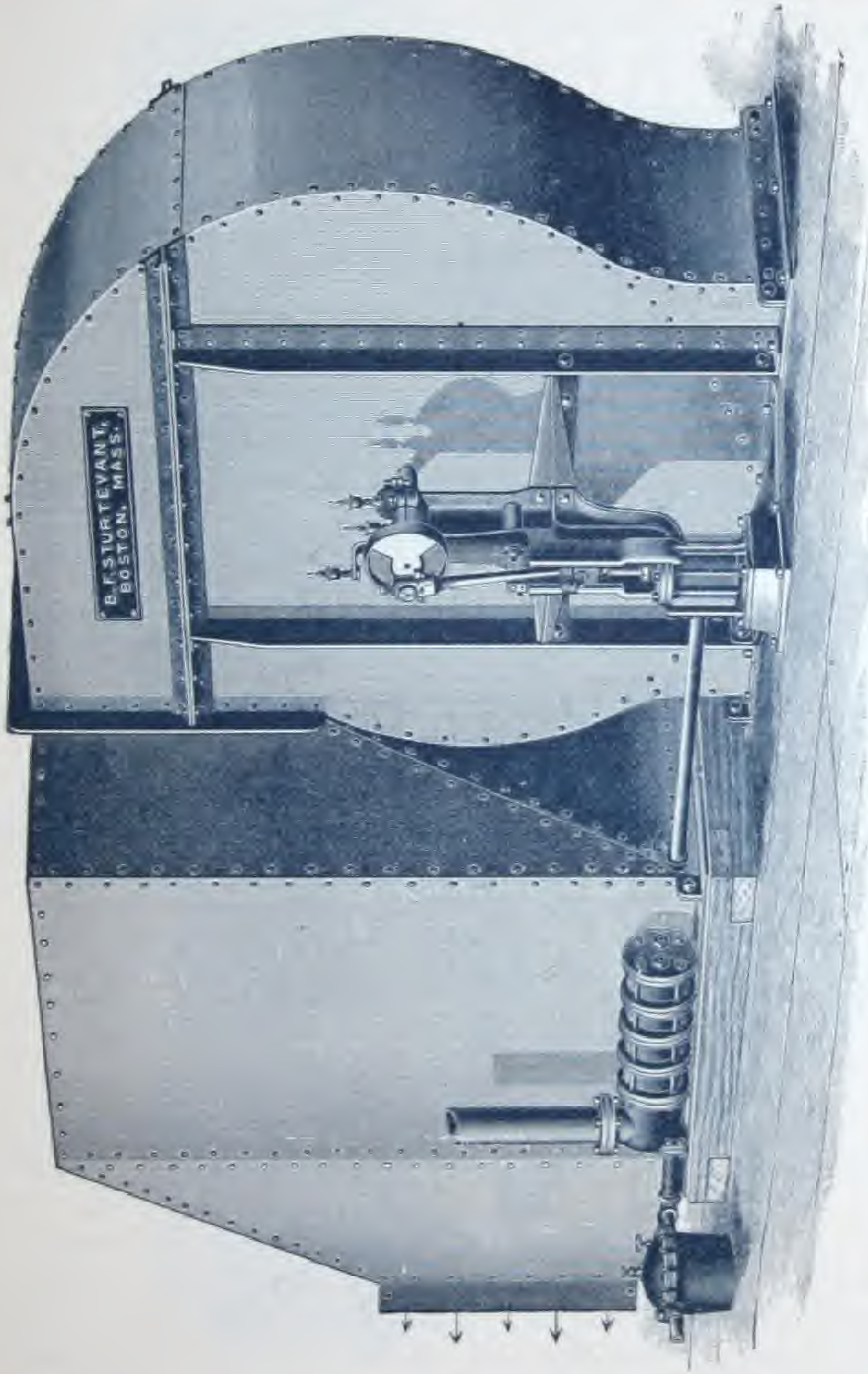



FIG. 50. HEATING AND VENTILATING APPARATUS,
ARRANGED TO BLOW THROUGH HEATER.

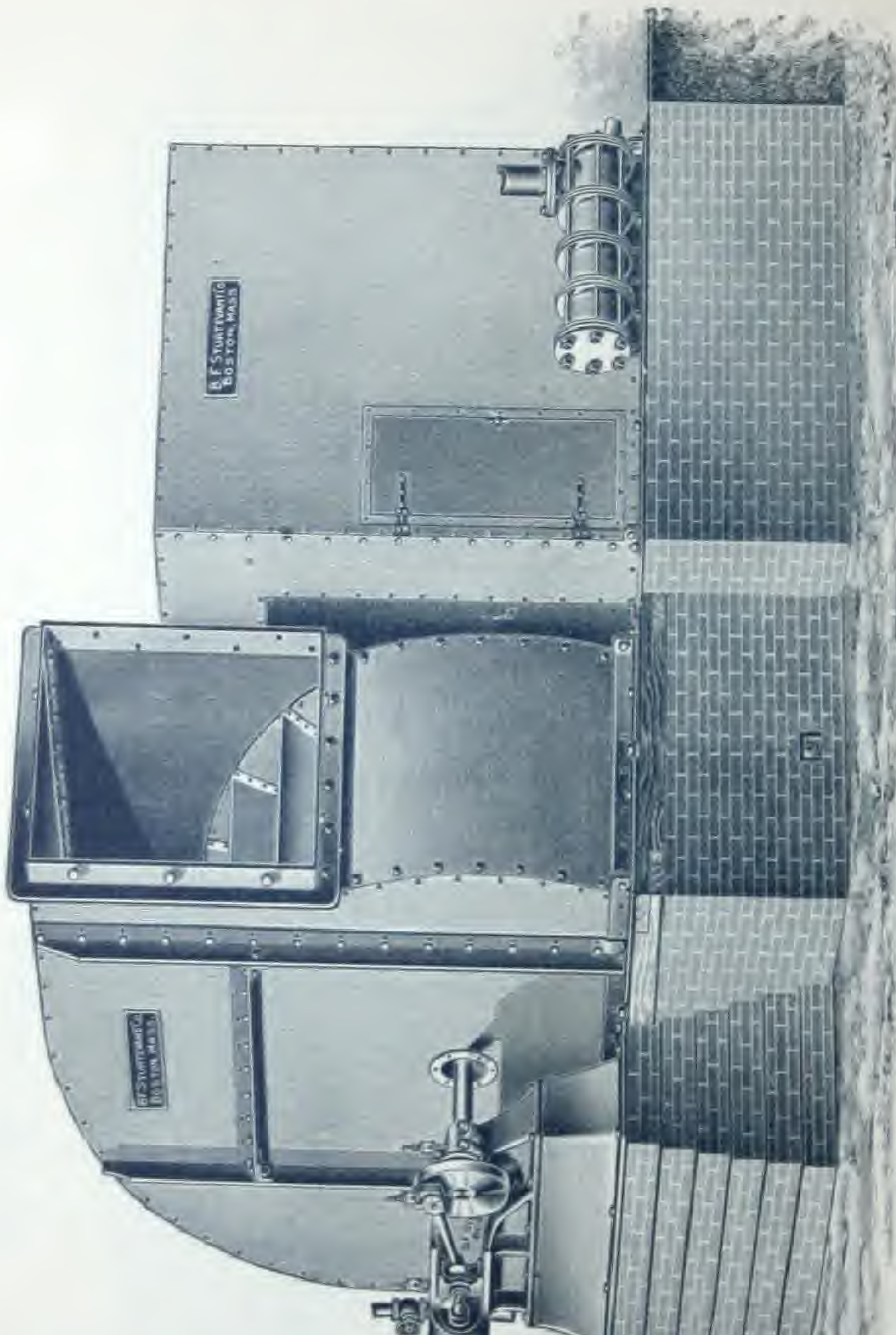


FIG. 51. STANDARD HEATING AND VENTILATING APPARATUS, WITH THREE-QUARTER HOUSING STEAM FAN.

STANDARD HEATING AND VENTILATING APPARATUS, WITH THREE-QUARTER HOUSING FAN. The three-quarter housing fans, in various types, have already been described. In combination with heaters they form a class of apparatus almost universally adopted where a plant of any reasonable size is to be installed in a basement. Such an apparatus, consisting of a three-quarter housing top horizontal discharge steam fan and sectional base heater, is illustrated in Fig. 51.

The inlet connection, which is shown between the fan and heater, is comparatively low, and practically forbids the use of a heater section much greater than its own height. The alternative, in order to provide a sufficiently large heater, is to build it in two groups, placed end to end and parallel to the side of the fan. Such an arrangement is adopted in the apparatus illustrated, although the heads of only one group can be seen. The group shown is provided with a large inlet and drip header, with connections for the use of exhaust steam.

The utility of an apparatus of this description must be evident where the heated air is to be conducted through pipes suspended beneath the ceiling. The height of the fan outlet is such as to make the discharge direct without change of direction.

BLOW-THROUGH HEATING AND VENTILATING APPARATUS, WITH THREE-QUARTER HOUSING PULLEY FAN. It must be obvious that a pulley fan may be as readily employed as a steam fan in connection with a heater. The former arrangement is represented in Fig. 52, but the heater is so located that the air is blown, rather than drawn, through it, the fan having an extra large outlet. Under such circumstances a blower can be as well used as an exhauster, and, where the air is to be taken from the apartment in which it stands, is much to be preferred.

The extreme length of a double group of ordinary sections placed end to end, and having sufficient heating surface, precludes such arrangement for a blow-through apparatus, because of the inability of the fan to distribute the air equably over the entire heating surface. But greater height is seldom objectionable, so that ample heating surface can usually be arranged in this manner.

As represented, this apparatus is fitted and flanged to utilize exhaust steam in two sections nearest the fan, while the remaining sections, separated from the former by a blank flange, are designed to be supplied with live steam. Evidently this type of apparatus possesses the same advantages as to adaptability to certain spaces as does the same arrangement with a full housing fan.

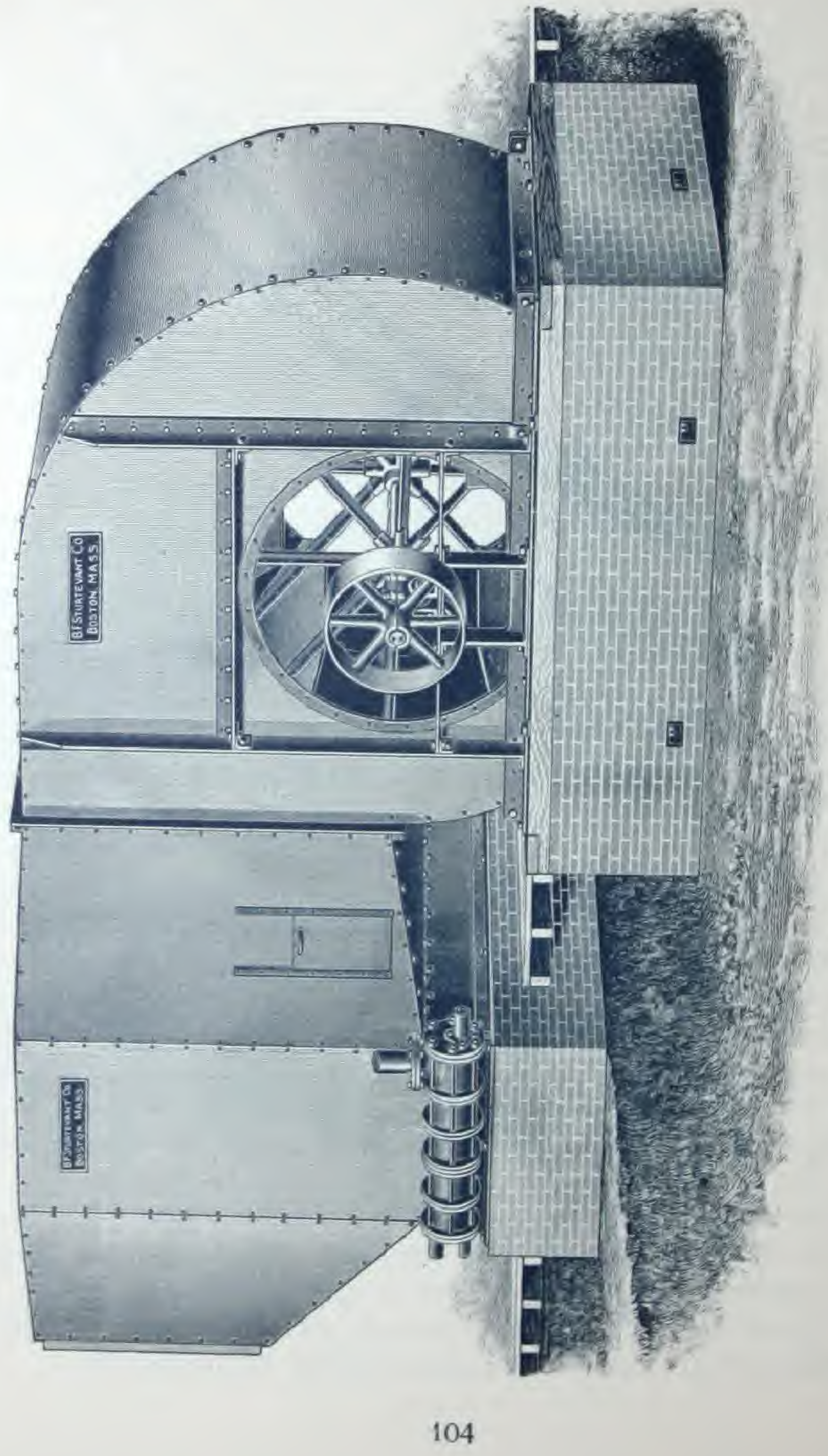



Fig. 52. Heating and Ventilating Apparatus,
arranged to blow through, with three-quarter housing pulley fan.

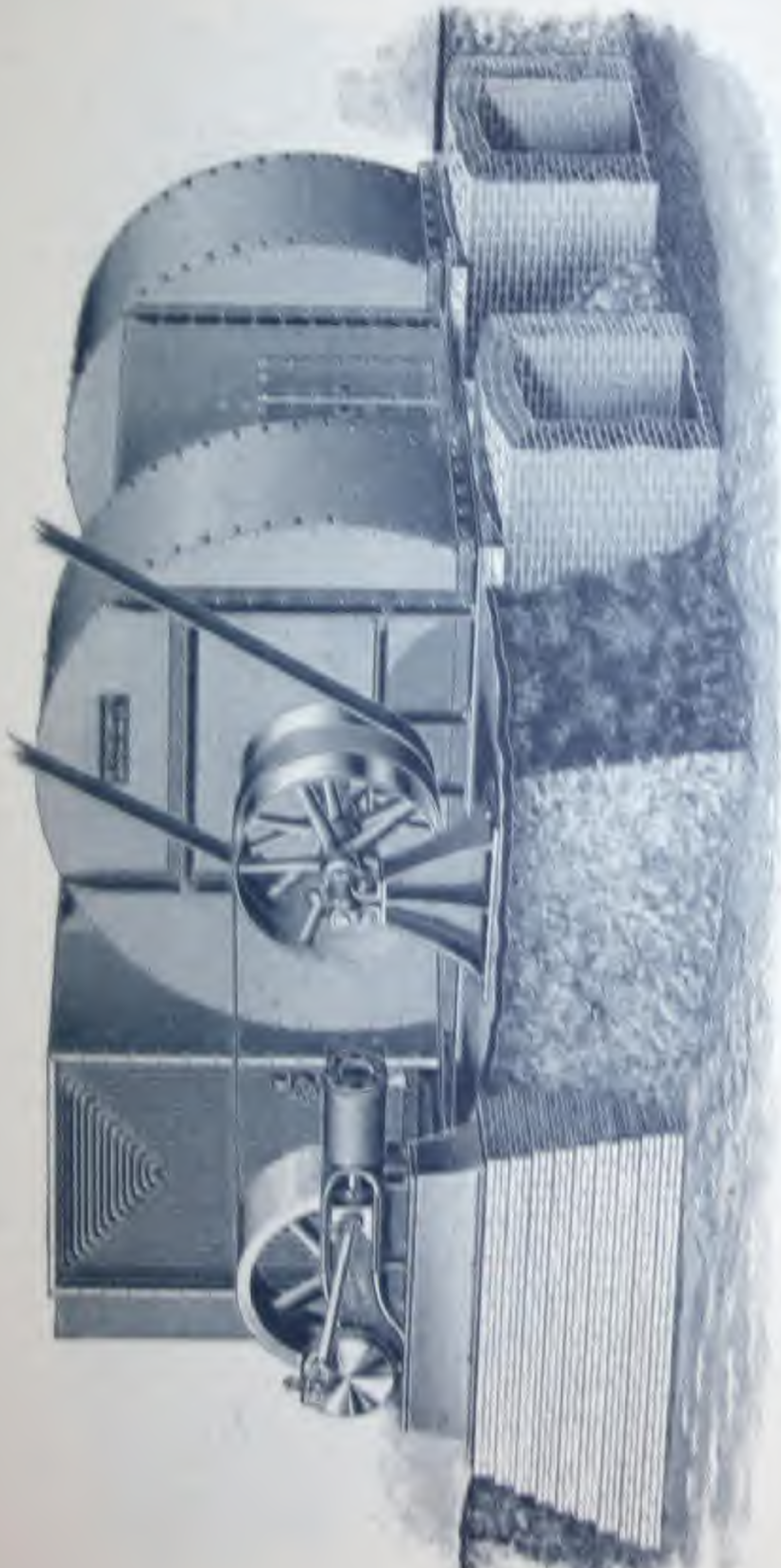


FIG. 53. DUPLEX HEATING AND VENTILATING APPARATUS,
WITH THREE-PULLEY RIG.


FIG. 54. HEATING AND VENTILATING APPARATUS,
FOR HOT AND COLD SYSTEM.

DUPLEX HEATING AND VENTILATING APPARATUS, WITH THREE-PULLEY RIG. The advantages of a duplex fan have already been pointed out, in that greater capacity can be secured within a given height, and the danger of inconvenience from accident is less.

Several arrangements of the heater are possible with the duplex fan, the most common being that shown in Fig. 53. The fans are built as exhausters, each with only a single inlet, and that on the side opposite the engine. These two inlet sides face each other, so that the entire space between the fans and connecting with these inlets can be readily enclosed and connected with the heater, which is usually symmetrically arranged and placed immediately behind the fans. The heater shown in the cut is constructed in three groups, forming three sides of a square, and offering a large area for the admission of air to the fans; only the open end of one group is clearly represented. The sections being arranged symmetrically, a uniform velocity of the entering air is secured through all parts of the heater.

This type of apparatus, when introduced for mill heating, is generally placed midway of the length of the mill, and discharges the heated air into a continuous brick duct extending along the wall on one side of the mill. The ducts from the two fans join before entering this main duct, and are provided at their junction with a gate which automatically regulates the discharge of air from the fans, and completely closes the outlet of either fan if it is stopped.

In textile and similar mill heating the heaters are designed to use, during the day, either exhaust steam from the mill engine, if it is non-condensing, or low pressure steam from the intermediate receiver, if the engine is condensing. The exhaust steam from the fan engines themselves is often sufficient to keep the mill comfortable during the night.

Pulley fans can be readily employed, and a special arrangement of tight and loose pulleys introduced, so as to allow of driving the fans by belt from the main line during the day, and by belt from a small independent engine during the night. This is the arrangement illustrated in Fig. 53. The engine is of the regular horizontal type, and is provided with an extra heavy fly wheel, with face of double width, to permit of the shifting of the belt.

The middle pulley upon the fan is rigidly keyed to the fan shaft. The other two pulleys, one on either side, are carried upon sleeves extending from the ends of the adjacent boxes. When the fan is to be driven by the engine, the belt from the latter is shifted on to the middle pulley, while that from the line shaft, which is usually standing still during the operation of the fan engine, is left idle upon the pulley nearest the fan.

# VENTILATION AND HEATING

HEATING AND VENTILATING APPARATUS FOR HOT AND COLD SYSTEM. It is evident that if an apparatus is to be employed to discharge either hot or cold air at will, the fan must be so located that it can force the air (not draw it) through the heater or by-pass around it. This arrangement, of the type very generally employed in schoolhouse and public building work, is represented in Fig. 54.

The fan is a blower constructed with extra large outlet, so as to secure the most thorough distribution of the air across the pipes of the heater. Above the heater pipes is provided a by-pass, in which is introduced a damper which may be closed to the passage of cold air, if desired. Two separate pipes conduct the air of the different temperatures away from the heater. The sections are made up in two groups, each arranged for separate steam supply and drip. When the distributing ducts are to be underground, or when it is desired to have the by-pass under the heater, the fan can be constructed with a bottom horizontal discharge, and the heater sufficiently raised, if necessary, to allow the air to by-pass beneath it.

The engine is of the low pressure horizontal type, controlled by throttling governor and arranged to drive the fan by belt. If desired, the engine could have been located beside the heater in such a way as to drive the apparatus from that end, and thus somewhat reduce the length of the plant.

Various other types of fans, engines, heating and ventilating apparatus, together with dimensions and capacity tables, are presented at length in the regular trade catalogues published by this Company.

# VENTILATION AND HEATING

## APPLICATION

OF THE

## STURTEVANT SYSTEM OF HEATING AND VENTILATION.

THE following illustrations and descriptions are introduced here simply as characteristic types of the application of the Sturtevant System of Heating and Ventilation, and as the most fitting testimonials to the efficiency of the system and apparatus introduced by this house. As has already been made evident, no two buildings require exactly the same arrangement,—special modifications being necessary to meet special conditions. The different types have been selected with care, as illustrating the variations in requirements and the best means of meeting them in buildings differing widely in construction and uses.

Of course, it is not to be understood that these are the only arrangements of this system that could have been adopted in the different instances, but, under the conditions here given, they appear to be the best. To the reader, however, these illustrations will certainly be suggestive, and, it is trusted, will make still more evident the possibilities of the system, and render its application more intelligible. The important factor in determining upon the manner in which this system shall best be introduced in a building is, first of all, the most convenient location of the apparatus, which in turn must, of course, be largely dependent upon the method of distribution of air to be adopted.

Economically considered, it is almost always best to place the apparatus near the centre of the building, so as to reduce the amount of ducts or piping to the minimum. Steam pipes of the size required for any given apparatus can always be extended at less expense than can main galvanized iron pipes from a given apparatus; therefore it is better to carry steam to the apparatus than to carry the apparatus to the steam.

Upon the following pages the various arrangements have been classified according to the type and character of the buildings in which they have been installed. All illustrations are from plants introduced by this Company, and now in successful operation; they therefore represent actual working examples of the application of this system, and by their variety bear emphatic testimony to the necessity of extended experience in deciding upon the best arrangement to be adopted.

# ONE-STORY BUILDINGS.

So far as their construction is concerned, the simplest of all structures requiring ventilation and heating are one-story buildings, such as mills, shops and exhibition buildings. But no other form of building has so large an amount of wall and roof surface per cubic foot of enclosed space, or such high and extended rooms; in fact, such a building, as a rule, forms only a single room. As a consequence the most efficient system is necessary; it is not alone sufficient that the apparatus shall be large, to allow for the excessive heat loss from the building, but, above all, the arrangement of the distributing ducts must be such as to most economically utilize the heat supplied; for underheating at the floor and overheating above is one of the most natural consequences of an imperfect system of distribution. Under such circumstances the apparatus itself is frequently condemned as having insufficient capacity, when the trouble lies entirely in the manner in which the heated air is delivered to the building.

In buildings of this type the principal provision is to be made for the heating, for the occupants are generally separated, and the air supplied for heating will answer all the requirements of ventilation. But it is nevertheless necessary that they should be provided with fresh air in sufficient quantity. One of the inherent virtues of this method of heating is that it ensures such supply. As the air provided is generally in excess of that required for ventilation, increased economy can be secured by using over again a portion of the previously heated air. This may be done by arranging dampers or doors so that part of the air entering the heater is drawn from out of doors and part, or, if desirable, the whole from the room. In fact, in the ordinary manufactory the common practice is to nominally take the entire air supply from within the building. This does not result, as might be supposed, in a total lack of ventilation, for a very considerable amount of outward leakage takes place through the walls and around windows and doors. Sufficient, indeed, to cause a similar inward, but imperceptible, leakage at other points in such quantity as to result in a comparatively frequent change of air within the building.

One of the greatest difficulties in a building of this character is to heat it rapidly in the morning, after it has cooled during the night. No other system can so completely and rapidly meet this requirement as that here presented. When it is desirable, the engine may be run slowly all night, and the building maintained at a moderate temperature. The exhaust from the engine being used in the heater, no expense is entailed for motive power.

GRANT LOCOMOTIVE WORKS, BOILER SHOP, CHICAGO, ILL.* As illustrated in Fig. 55, this building is of the simplest type of modern one-story shop. Its width demands light at the centre, which is provided by the monitor, the introduction of which, however, has a marked influence in determining the method of hot air distribution to be introduced.

As a rule, it is undesirable to attempt to place the piping on one side only and blow the air across such a building, because of its tendency to rise to the monitor in the centre. The principle generally followed is to discharge it entirely around the building and toward the outer walls. To this end, the apparatus is placed upon a platform, for the double purpose of economizing floor space and providing for the natural return of the water of condensation to the boilers without the use of a return water apparatus.

FIG. 55. GRANT LOCOMOTIVE WORKS, BOILER SHOP, CHICAGO, ILL.

By this arrangement the fan is enabled to discharge the air directly into a line of horizontal piping extending around the entire building at some distance from the walls. At proper intervals outlets are provided, through which the air is delivered in such a direction as to strike the floor near its intersection with the outside walls. The most vulnerable point is thus attacked, and a warm barrier of air interposed between the occupants and the cold walls.

The natural course of the air thus discharged is backward along the floor to the centre of the building, where it rises to the monitor above, if it still retains sufficient temperature to cause it to take this direction.

A very satisfactory arrangement in a building of this construction consists in supporting the apparatus overhead upon the trusses, near the centre of the building. Connection is then made to a system of piping located and discharging exactly as here shown.

* Purchased by SIEMENS & HALSKE ELECTRIC CO., OF AMERICA, since the system was installed.

CARNEGIE STEEL CO., LTD., HOMESTEAD STEEL WORKS, MUNHALL, PA. Notwithstanding the remarks upon the preceding page, there are certain conditions under which the hot air may all be supplied from one side of a building, of the type shown in Fig. 56. Here the manufacturing processes carried on within the building have much to do with the success of the arrangement. As indicated in the cut, the apparatus is placed upon the floor upon one side of the building, and midway of its length.

FIG. 56.
CARNEGIE STEEL CO., LTD.
HOMESTEAD STEEL WORKS, MUNHALL, PA.

From the outlet, which discharges directly upward, the pipe branches into two, running in either direction nearly the entire length of the building. In addition, at the fan outlet, the pipe is provided with a large outlet, so located as to discharge a large volume of air downward and directly across to the other side of the building. As the horizontal pipes extend toward the ends of the building, they are provided with outlets upon either side, delivering the air towards the floor and the opposite sides of the building.

Where air is to be forced long distances in such a building, it is necessary that its individual volume be large; that is, that for a given volume of air delivered, a small number of large outlets is preferable to a large number of small ones. With the former arrangement the body of air seems to maintain a certain compactness as it flows, and is not relatively so easily dissipated as would be the case with a smaller volume.

Under certain circumstances most excellent distribution of air can be secured by forcing it in quantity, without piping for a long distance, lengthwise of such a building. Naturally, with such an arrangement, where the minimum of piping is used, it is best to locate the outlets so that the air will be delivered near to and will follow the line of the side walls.

# VENTILATION AND HEATING

PITTSBURG, COLUMBUS, CINCINNATI & ST. LOUIS RAILWAY CO., PASSENGER CAR PAINT SHOP, COLUMBUS, O. The construction of a car paint shop is materially different from that of the ordinary one-story structure. This difference is most evident in the character of the roof, which is covered with a series of monitors, each corresponding to a line of track beneath. This arrangement, together with the presence of cars within the building, practically prevents the supply of air by forcing it horizontally from overhead outlets.

Fig. 57 clearly indicates the best method to be adopted. Here the apparatus is located in one corner of the building, and the air is distributed through an overhead system of galvanized iron piping, extending entirely around the

FIG. 57. P., C., C. & ST. L. RY. CO.,
PASSENGER CAR PAINT SHOP, COLUMBUS, O.

inside of the building at some distance from the walls. Between each pair of tracks pipes are brought down, so as to deliver the air very near the floor, where it naturally spreads, and whence it gradually rises in a well-distributed mass.

One of the important advantages of the introduction of this system of heating in a building used for this purpose lies in the increased rapidity with which the cars may be dried, owing to the large volume of fresh air constantly coming in contact with the paint. In other words, with this system the same number of cars can be dried in a given time in a smaller building than by the usual methods — certainly an important element in deciding upon the system to be adopted.

# VENTILATION AND HEATING

CHICAGO, ST. PAUL, MINNEAPOLIS & OMAHA RAILWAY CO., ROUNDHOUSE, EAST ST. PAUL, MINN. The proper heating of a roundhouse presents a double problem, for not only must its temperature as a whole be kept uniform and sufficiently high, but provision must be made, where heavy snow storms are prevalent, for rapidly melting from the running gear of the locomotive the burden of snow and ice with which it is so frequently encumbered when first returned to the roundhouse from a long run. The general method of solving the problem is made evident in Fig. 58. An overhead system, with hot air discharged toward the walls, serves for the general warming, while special pipes, to be used when desired, conduct large volumes of air to the pits, where it is well distributed beneath the locomotives.

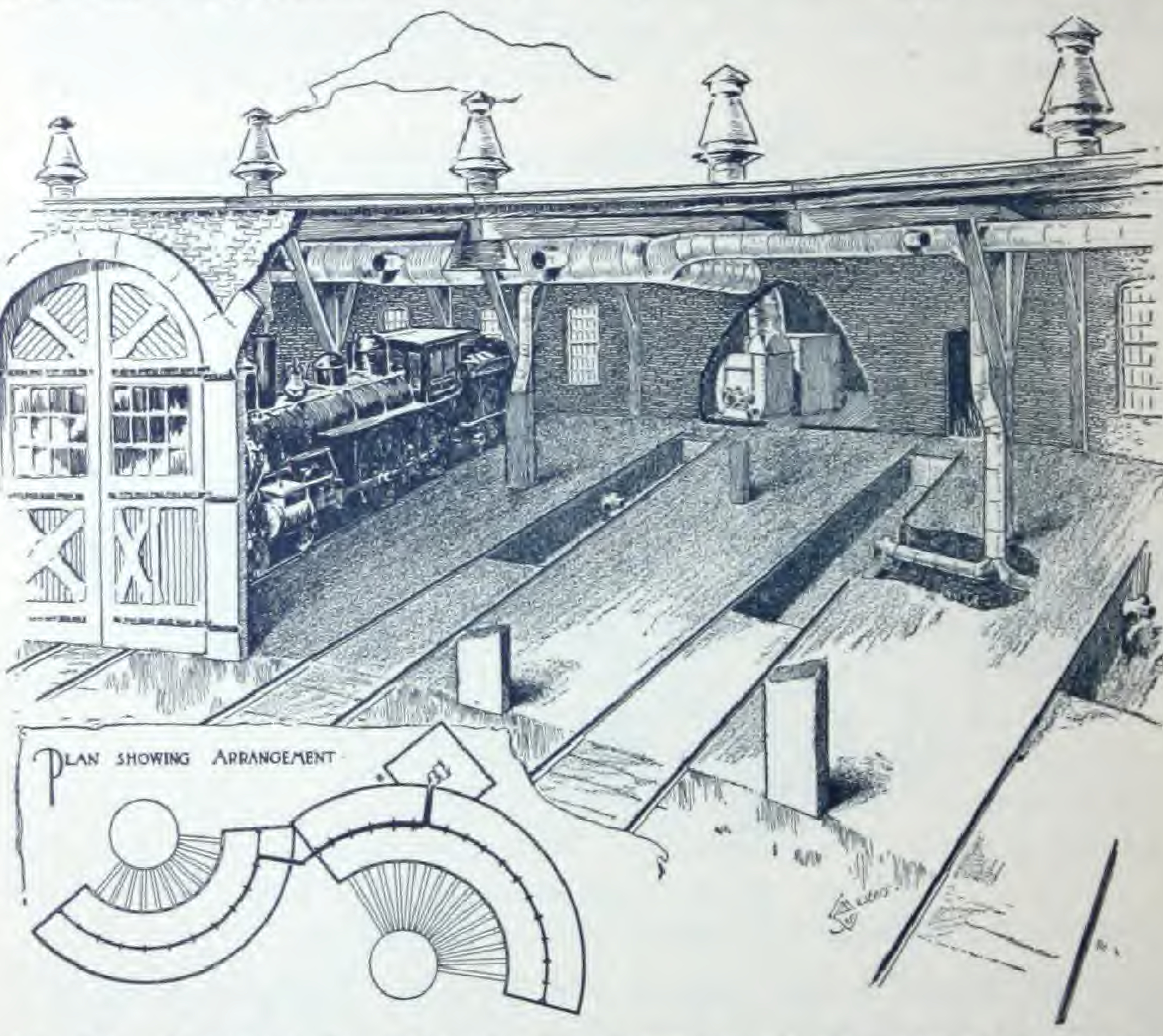



FIG. 58. C., ST. P., M. & O. RY. CO.. ROUNDHOUSE, EAST ST. PAUL, MINN.

# BUILDINGS OF MORE THAN ONE STORY.

As the number of stories in a building increases, so do the complications in the manner of heating the same. It is no longer a simple matter of blowing the air from the fan outlet directly into the single floor, or, even in the more extended arrangement, of conducting it around the building in pipes and discharging it at suitable intervals. In the multi-storied building the simplest arrangement that can, in many cases, be sought is the duplication upon each floor of the scheme that prevailed in the one-storied building.

There is this to be said, however, in favor of the building of more than one story, namely, that its flat ceilings and the relatively small distance from floor to floor as compared with the height from floor to roof in a one-story building make the matter of distribution of the air once discharged to a given floor very much easier. With smooth ceilings, unobstructed by beams, shafting or belting, air discharged horizontally at high velocity just beneath them may be forced for long distances, as to the opposite side or end of the room, before its volume becomes seriously dissipated. Of course, this movement reduces to just this extent the necessity of distributing pipes.

But where beams exist, extending below the ceiling, opposing their faces at right angles to the direction of the air movement, the currents are very quickly broken up, and it is impossible to compel the air to move a great distance beyond the outlet. The influence of shafting, with its revolving pulleys, and of a mass of moving belts, is very noticeable in a manufactory, particularly a textile mill. Under such conditions, if the air supply openings are sufficiently numerous, this moving machinery plays a most beneficent part, and thoroughly mixes the fresh air with that prevailing in the room.

In deciding upon the arrangement of ducts and flues in a building of two or more stories and exceeding 50 feet by 100 feet in floor plan, two principal methods appear. First, the introduction upon each floor of a complete system of overhead piping, extending lengthwise of the building, with outlets at intervals, the pipes upon the various floors being fed by a single stand pipe at some convenient point. Second, distribution from a number of vertical flues placed at intervals down the centre or along the side of the building, each discharging to each floor, and all being supplied by a main duct in the basement or lower floor. In its ideal form, this is the arrangement adopted in textile and similar mills where the flues are built of brick on the outside of the building and along one side. Of course, it is evident that such a construction must be decided upon before the erection of the building is begun. In fact, although too

Fig. 59. Grant Locomotive Works,
Machine and Erecting Shops, Chicago, Ill.

seldom the case, it is very desirable that the location and arrangement of even a galvanized iron distributing system should be determined before work has progressed too far. Delay in this matter frequently causes great inconvenience in the introduction of the system, which, when appreciated, cannot be readily overcome. This is particularly true with reference to the location of shafting, belting and machinery, which, in many cases, might just as well have been differently arranged had it been known that interference with direct lines of distributing pipe might have been avoided.

GRANT LOCOMOTIVE WORKS, MACHINE AND ERECTING SHOP, CHICAGO, ILL.* In the modern machine shop it is now a common practice to introduce an intermediate or gallery floor, the entire height of the structure being made sufficient therefor. Such an arrangement in one of its forms is shown in Fig. 59.

The portion of the wing shown upon the right is fitted upon one side with an extensive gallery upon which the apparatus stands. Part of the air discharged therefrom is delivered from an overhead pipe to the gallery itself, while the main floor is supplied through down-pipes from this large main and also by special outlets direct from the fans themselves.

The wing upon the left was designed for the erection of locomotives, and is provided with tracks and pits. The system, as introduced in this part of the building, is duplex, part of the air being supplied above head level by risers against the wall along which it is blown. This supply is supplemented by air delivered to the pits from an underground duct running lengthwise of the building just back of the pits. By these two methods of supply the warm air is well distributed at floor level, a vital feature in the heating of such a building. As will be noted from the illustration, the apparatus is duplex and of the three-quarter housing type, but provided with a sheet iron lower portion (not seen in cut), suspended below the platform. These fans are, in effect, full housing fans, with their foundation angle irons attached part way up their sides.

Some idea of the magnitude of this plant may be formed from the statement that the main machine shop is 340 feet long by 110 feet wide and 66 feet high at its highest point. The wing devoted to the erection of locomotives measures 85 feet by 300 feet on the floor, and is 54 feet high to the ridge. Each of the two fan wheels in the apparatus is 10 feet in diameter by 5 wide, and the heater contains 19,500 lineal feet of one-inch steel pipe.

* Purchased by SIEMENS & HALSKE ELECTRIC CO., OF AMERICA, since the system was installed.

LINK BELT MACHINERY CO., CHICAGO, ILL. The true type of the so-called gallery shop is clearly represented in Fig. 60, as is also one of the most convenient methods of heating the same. As one of the inherent features of such a construction is a crane travelling down the centre the entire length of the building, it is obviously impossible to carry pipes from one side to the other unless they are placed underground or run up overhead. Even the latter arrangement is frequently impracticable.

The size of such a building, however, generally warrants the introduction of two apparatus in the manner shown, the apparatus and piping upon one side being an exact duplicate of that on the other. Each fan is provided with a

FIG. 60. LINK BELT MACHINERY CO., CHICAGO, ILL.

double discharge, so that a portion of the air is discharged into the overhead system, whence it is forced toward the outer walls of the gallery, while the remainder of the air delivered by the fan passes into the duct beneath, from which the lower floor is similarly supplied.

This arrangement requires but little room for the apparatus, while the piping is so located as to be entirely out of the way, noticeably so in the case of the line running overhead in the gallery. The direction of discharge toward the outer walls is exactly what is desirable to secure its proper movement through the cooling action of the walls, and, altogether, the plant harmonizes in simplicity and symmetry with the building itself.

GEO. F. BLAKE MFG. CO., EAST CAMBRIDGE, MASS. In the building just illustrated the frame was entirely of iron. In Fig. 61 is shown a building almost identical in proportions, but framed throughout of wood. While the arrangement for heating and ventilating introduced in the former would have operated efficiently in the latter, nevertheless, to meet certain conditions upon the part of the owners, an entirely different method was adopted.

Here it was desired that only a single apparatus should be installed, and that this should be located beside the engine and boiler room. Accordingly, a fan with three-quarter housing was introduced and arranged to deliver the heated air into an underground duct. This duct, after supplying branches, one to its right and one to its left, upon the side of the building nearest the apparatus, was carried across underground to the opposite side of the building, where it delivered the remaining volume of air into another duct running nearly the entire length of that side.

FIG. 61. GEO. F. BLAKE MFG. CO., EAST CAMBRIDGE, MASS.

From these side ducts rectangular galvanized iron flues were carried up, each flue having openings on its sides about nine feet above the main and gallery floors. The air is thus discharged longitudinally along the walls. Owing to the large number of outlets, a very equable distribution is secured, resulting in uniformity in temperature and ventilation. So far as the apparatus itself is concerned, its location is by far the most desirable for economy in attendance, while its floor area is manifestly less than that required for two apparatus of the same capacity.

COPEWELL HORSE NAIL CO., HARTFORD, CONN. A somewhat unique structure is shown in Fig. 62, the upper portions of the space in the centre being formed into a second floor. The apparatus, which is of the blow-through type, is supported upon the trusses just below this floor and midway of the length of the building. From either side of the heater there extends a horizontal pipe nearly down to the end of the building. Branch pipes from these mains are carried downward and outward to the side bays, into which the air is directly discharged, none being delivered to the centre of the building.

FIG. 62. COPEWELL HORSE NAIL CO., HARTFORD, CONN.

From the top of the heater another pipe, extending upward, supplies a horizontal main with its series of outlets for the second floor. Evidently, both upon the main and the second floor, the apparatus and piping occupy the minimum of space.

Here the location of the apparatus itself had a marked influence upon the method of heating to be adopted. The apparatus is almost exactly in the centre of the building, and is arranged to take its supply from the building itself, when desired. When so doing the air delivered at the most distant points, that is, in the outer bays, is gradually drawn inward to the large centre bay, heating it, so far as its lesser requirements demand, and finally passing again through the fan. Had a less extended system of piping been adopted, the tendency toward a vacuum in the vicinity of the fan, although scarcely perceptible, would have extended a powerful influence to prevent the air reaching the extreme ends and sides of the building before its return to the fan.

GLENS FALLS PAPER MILL CO., FORT EDWARD, N. Y. The ready adaptability of the Sturtevant System to meet the varied requirements of the paper mill is evidenced in Fig. 62, which represents a thoroughly-equipped sulphite pulp and paper mill of large proportions.

In the wood room, shown in the foreground at the extreme left, is located a large apparatus, arranged to heat both the first and second floors of this building, as indicated, and also to supply the wet-machine, digester and acid houses, which, in their respective order, adjoin the wood room on the right. A second apparatus of still greater capacity is located in the finishing room, shown just over the bridge in the illustration. From this apparatus the first and second floors are supplied, while branch pipes extend down the centres of two of the

FIG. 62. GLENS FALLS PAPER MILL CO., FORT EDWARD, N. Y.

machine rooms, and thence across the beater engine room to the large machine room on the right. A third and smaller apparatus, shown just beyond the larger one just described, supplies still another machine room in the extreme background.

In the case of the machine rooms which are supplied with roof ventilators, the principal duty of the system is to prevent the deposition of moisture upon the ceiling, and, therefore, the air is discharged more directly in its direction. The moisture-absorbing quality of the heated air enables it to immediately take up and render invisible all vapor, thus preventing the usual great annoyance from this source. When desired, an apparatus designed for supplying other buildings besides the machine room may be arranged to supply cooler air to the latter, as an offset to the heating effect of the drying cylinders. In the digester and acid houses, as well as in the grinding room in a ground pulp mill, the ventilating and moisture-absorbing features of the Sturtevant System are indispensable.

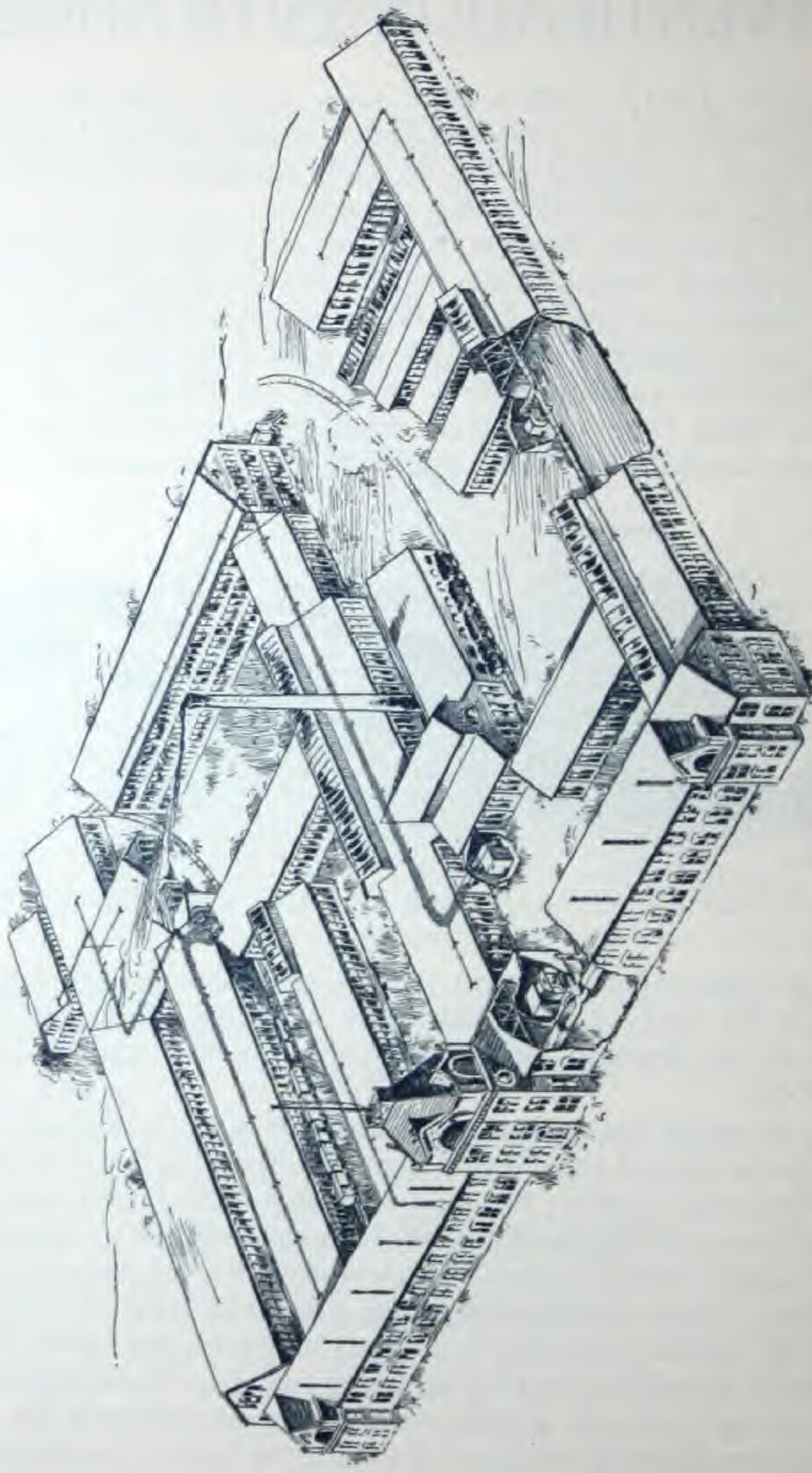


FIG. 64. WHITMAN & BARNES MFG. CO., WEST PULLMAN, ILL.

# VENTILATION AND HEATING

WHITMAN & BARNES MFG. CO., WEST PULLMAN, ILL. It is doubtless evident, from what has preceded, that there is practically no limit to extent of the buildings for the heating of which the Blower System may be applied. As buildings increase in size the question becomes still more pertinent as to whether one or more apparatus should be installed. There certainly is a limit at which the cost of piping and ducts for a single apparatus, plus the cost of the apparatus itself, exceeds that for two apparatus and their connecting piping, for with the former arrangement the air often has to be carried long distances before it can be directly applied for heating.

The question of the number of apparatus is, therefore, one that is usually first presented in the case of an extremely large or complex plant, and, furthermore, one that demands the most careful consideration from an economical standpoint. A most excellent example of the solution of such a problem is presented in Fig. 64. Here an enormous plant consists of numerous buildings of varying size, construction and uses. It was undesirable to carry any piping or ducts either overhead or underground between the buildings. Exhaust steam, produced by the main shop engine, was to be utilized so far as possible.

A careful study of the sketch will make evident the general scheme. For the main structure on the front a single apparatus was installed, midway of its length, in a special small building built at the back. An underground duct from this apparatus supplies a series of pilaster flues, also upon the back of the building. Each flue is provided with outlets, one to each floor.

The central heating plant next to the engine room, the position of which is between the chimney and the observer, supplies the main central building, which is of one story with pitch roof. The pipe, supported in the middle of the building upon the roof trusses, discharges the air at intervals downward and toward the walls. In the extreme rear a three-story building, requiring heating only in the upper floor, is supplied in a similar manner, the pipe being carried overhead. Economy in galvanized iron distributing pipe would have dictated that this apparatus should have been placed nearer its centre of distribution, rather than at the end of the piping system. But the practical difficulties in the way of so locating the apparatus, on account of the room it would occupy, compelled its location in a single special building adjoining the engine house.

The general arrangement of the other two systems is substantially the same. In both of these latter cases the apparatus is exceptionally well located as regards economy in the distributing pipe, and in both the apparatus is installed in a building constructed for the purpose, so that no valuable floor space within the main buildings is occupied.

C. H. MOULTON & CO., BROOKFIELD, MASS. In modern shop construction nothing is more symmetrical or better adapted for a simple installation of a galvanized hot air piping system than the frame shoe shop, of which a typical building is presented in Fig. 65. Here the basement is substantially a cellar, the centre of which is surrendered to the heating apparatus. This consists of a three-quarter housing fan, with top horizontal discharge, driven by a horizontal engine, and drawing air through the heater.

From the outlet of the fan extends a system of piping suspended just beneath the first-floor beams. At the centre of the building, and at points some 40 feet from the ends, are carried up vertical risers, provided with outlets through which each floor is supplied. The central pipe is arranged with four outlets upon each floor, so that the discharge is at an angle of 45° with the walls. The end risers have each only two outlets on a floor from which the air is forced toward the adjacent corners.

FIG. 65. C. H. MOULTON & CO., BROOKFIELD, MASS.

The enormous glass area, the rather open construction and the numerous employees, seated in large numbers near the walls, demand the maximum supply of warm air and the greatest care in its distribution, which latter is best secured by the arrangement shown.

Under other circumstances the pipes might have been placed against one wall, with outlets arranged both to discharge along the wall and across the building.

# VENTILATION AND HEATING

PELZER MFG. CO., PELZER, S. C. In no class of manufacturing buildings has the adaptability of the Blower System been more carefully considered than in the textile mills; and yet this is but natural when the perfection of all appointments in such structures is considered. The general similarity of construction in buildings of this character has greatly facilitated the standardizing of details in connection with the heating, ventilating and moistening system.

Modern mill construction, as exemplified in the textile mill, is generally considered to be evidenced in brick walls, numerous and large windows, wooden floor framing consisting of large timbers extending across the mill at intervals of about 10 feet, supported by the walls and by wooden columns, the floor being of 3 or 4-inch plank with 1-inch top finish. Such construction is simplicity itself.

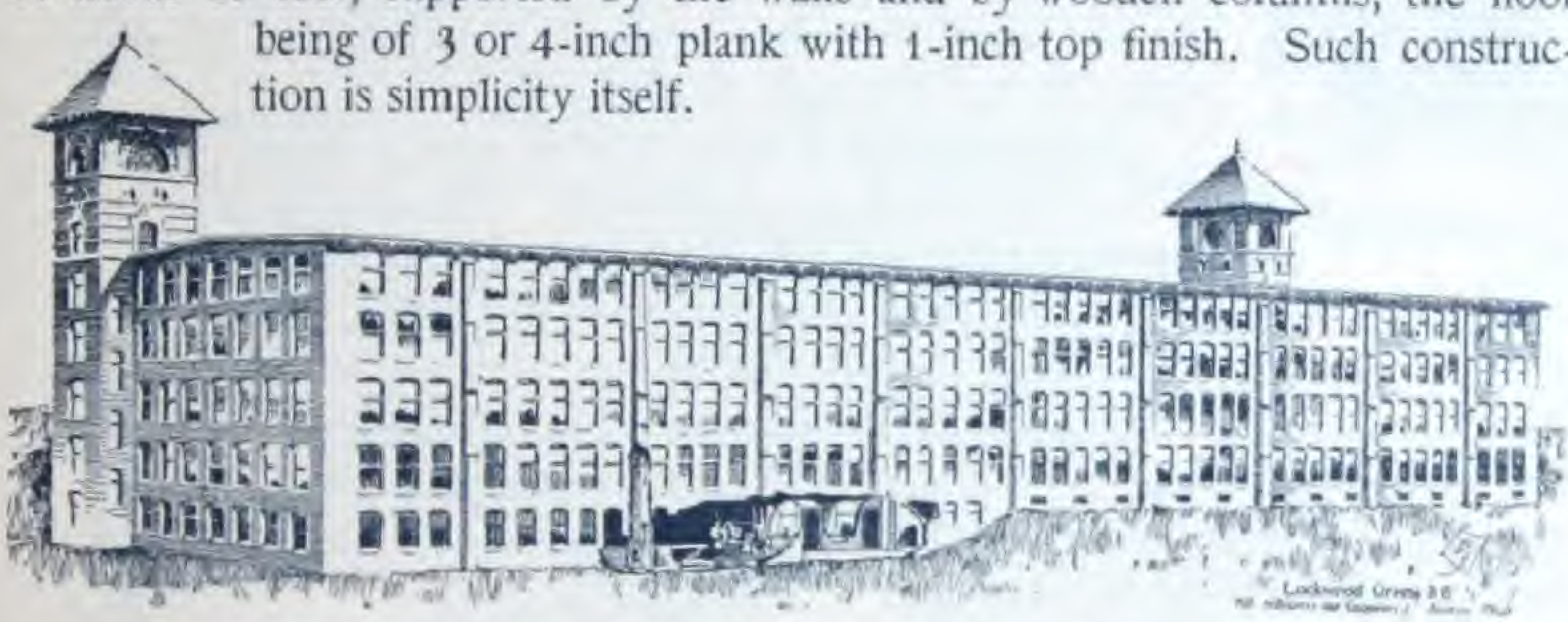


FIG. 66. PELZER MANUFACTURING CO., PELZER, S. C.

The uniform size and arrangement of the machines within such a building naturally compels the preservation of straight and ample passageways between the individual machines, as well as around them next to the walls. Evidently there is no practical opportunity for the introduction of heating flues anywhere within the building, because of their serious interference with such uniformity. But the brick walls present a most convenient location for flues of the requisite area.

In one of the forms adopted, such flues, projecting outward from the building, as illustrated in Fig. 66, are placed along one side of the structure only, and at intervals of 40 to 70 feet, according to the character and construction of the building. In the basement, or ground floor, nearly midway of its length, is located the apparatus, usually of the type known as the three-pulley rig, as shown in Fig. 53, so arranged that the fans may be driven by the mill engine during the day, and, if necessary, during the night by the special fan engine provided for the purpose.

Extending along the floor upon which the apparatus stands, or beneath it, if desired, is a brick duct formed upon one side by the wall of the building itself. This duct, in its most approved type, forms in section what is known as a quadrant arch, as shown in Fig. 67. Connection from this duct is made with each pilaster flue, the duct being gradually reduced in area as air is thus discharged from it.

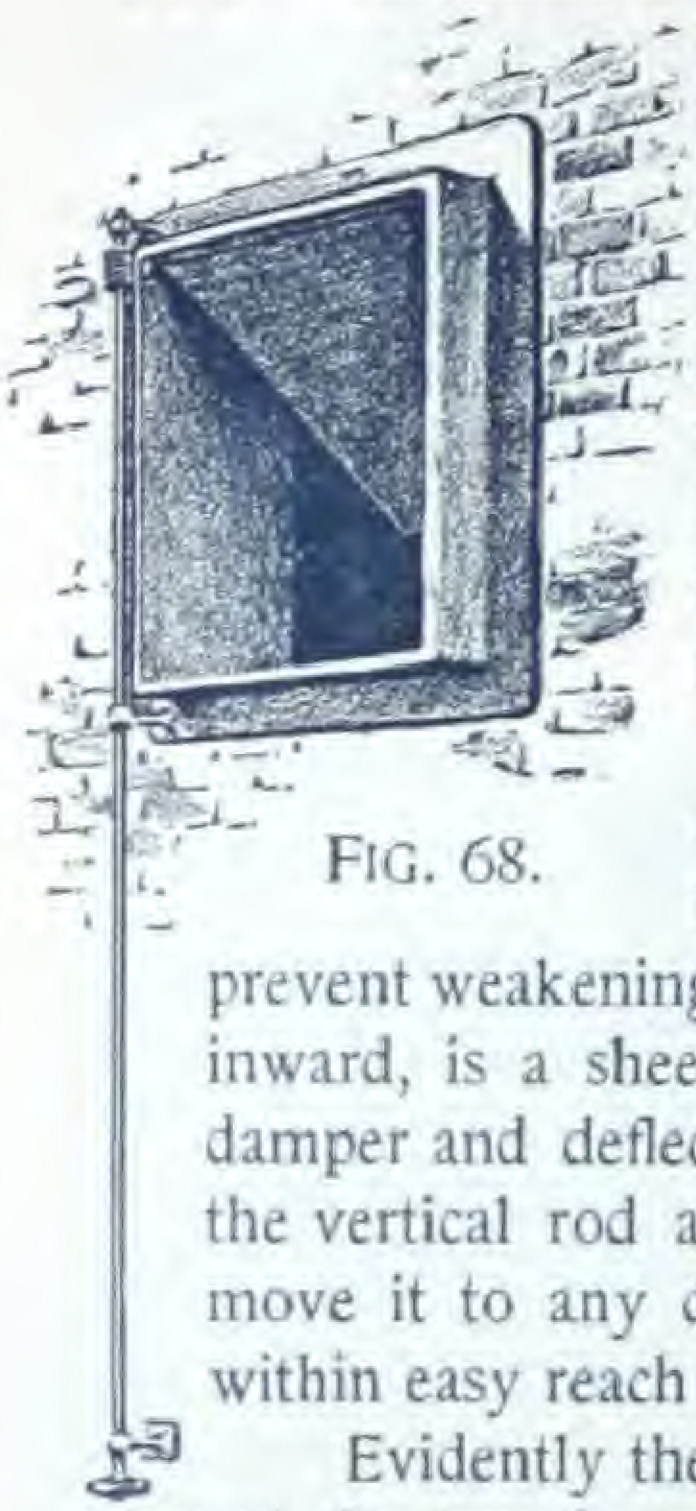


FIG. 68.

The flue, as will be noted, is also decreased as it extends upward, to compensate for the air delivered to the various floors. Its general construction must be evident in Fig. 67. At a sufficient distance below the floor beams, to avoid weakening the construction, outlets are provided from this flue into each of the floors.

Each opening, in turn, is fitted with a special damper of the type presented in Fig. 68. This consists of a cast-iron frame bricked into the wall, and sufficiently strong to prevent weakening the same. Pivoted at the top of this frame, and swinging inward, is a sheet-iron plate, serving the double purpose of damper and deflector, and adjustable by a worm on the end of the vertical rod acting upon a gear upon the damper axis to move it to any desired position. The rod extends down to within easy reach of the operative.

Evidently the result of such an arrangement of the Sturtevant System in connection with a building of the character described is to provide the most excellent opportunity for successful heating from one side of the building only. The smooth ceilings, without beams to interfere with the movement of air directly across the building, make it possible to fully supply the side farthest from the flues, while the moving pulleys, belting and shafting which intervene, fortunately present just enough opposition to sufficiently break up these air currents and thoroughly mix the air throughout the room. Although, conditions permitting, it is usually advisable to place the flues upon the least exposed side of the building and discharge the air toward the colder side, nevertheless, in practice, the effect of location of flues is seldom perceptible in such a structure. The entire subject of heating, ventilating and moistening mills is exhaustively treated in a special catalogue.

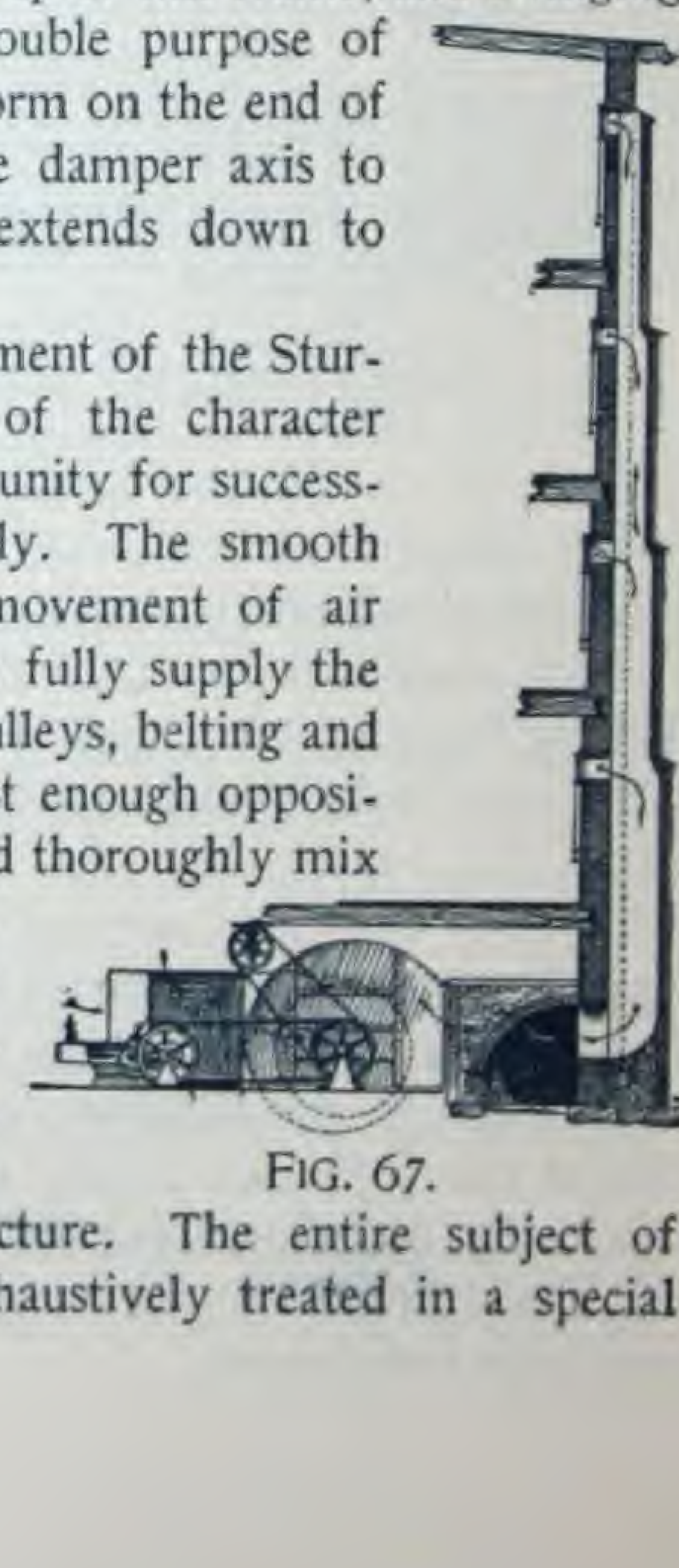


FIG. 67.

PACIFIC MILLS, LAWRENCE, MASS. In the arrangement just described each individual flue supplies heated air to each of the floors of the building. A somewhat different arrangement is presented in Figs. 69, 70 and 71. In this latter building, which was designed distinctively as a yarn mill, no projecting pilaster flues were introduced, but each pier between the windows along one side of the building was provided with an internal rectangular tile lining serving as a flue, and as indicated in Fig. 70. Each individual flue supplies air to only a single floor, so that, there being three floors, every third flue supplies the same floor. As the piers are located 10 feet apart, this brings the openings on each floor 30 feet apart, making them even more numerous than with the ordinary pilaster arrangement. Evidently in a building of four stories the openings would, under similar conditions, be 40 feet apart. Each flue opening is fitted with a special form of damper somewhat different in construction from that already shown in Fig. 68.

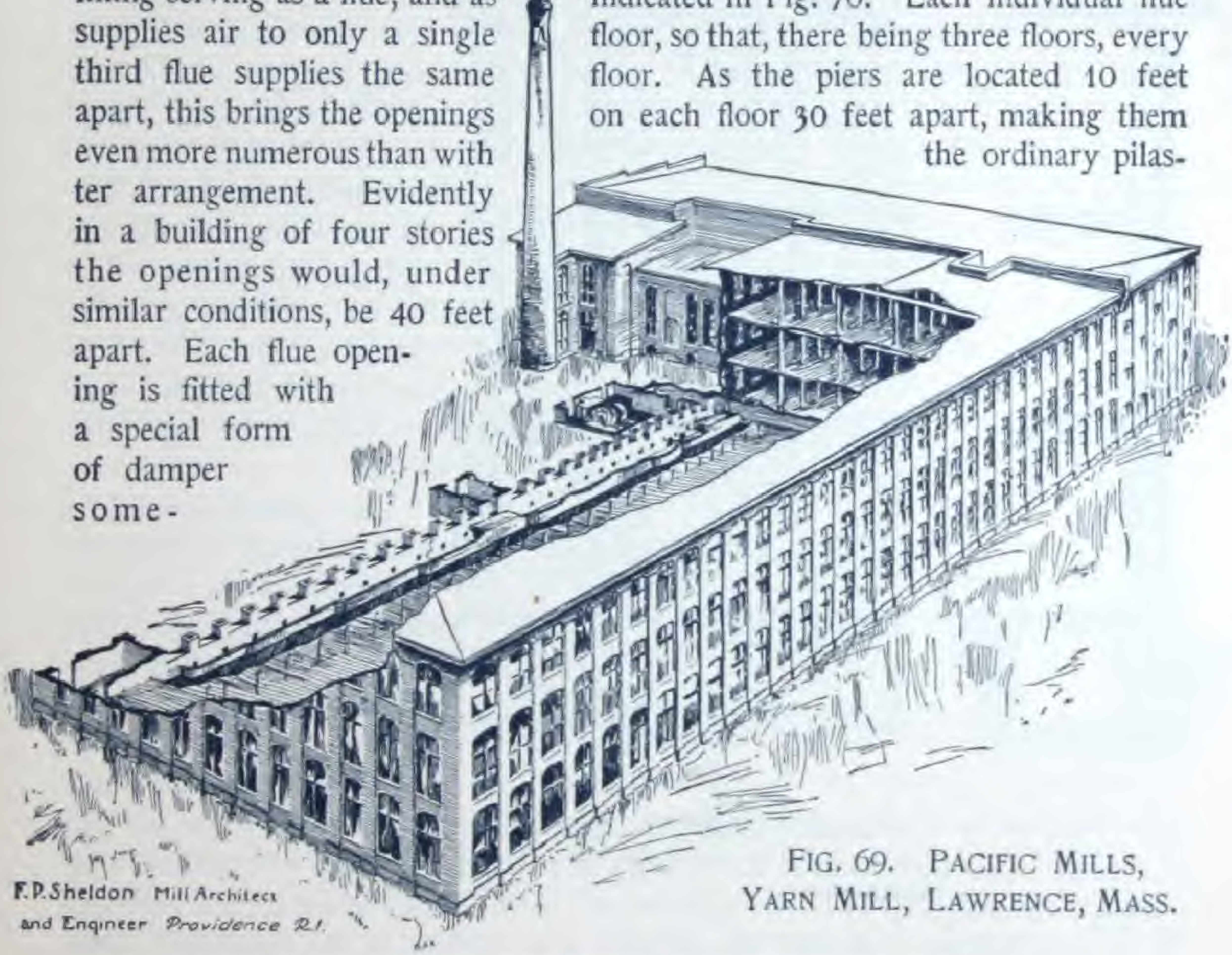



FIG. 69. PACIFIC MILLS, YARN MILL, LAWRENCE, MASS.

This arrangement of flues avoids the break in architectural harmony resulting from the introduction of the pilaster flues, but at the expense of greater multiplicity in flues and openings and in greater opportunity for loss of heat, which is, however, materially reduced by the use of the flue linings. Each flue connects at its base with the main horizontal duct, of which the building wall forms one side. The top, which is arched in form, is constructed

of corrugated sheet iron, covered level with cement. Such an arrangement is both strong and serviceable, and is to be preferred substantially in this form wherever the duct has to be excavated. Another scheme of top covering consists in laying brick upon tee irons extending at proper intervals across the top of the duct. As is evident in Fig. 71, reduction in area as the duct progresses is in part secured by raising the level of its bottom, which, in consideration of the cost of excavation, is more economical than lowering the top. Under all conditions the duct should be kept as nearly square in cross sections as the circumstances will permit, thereby saving material and reducing the superficial area and the losses by friction of moving air, which would be incurred by any other form.

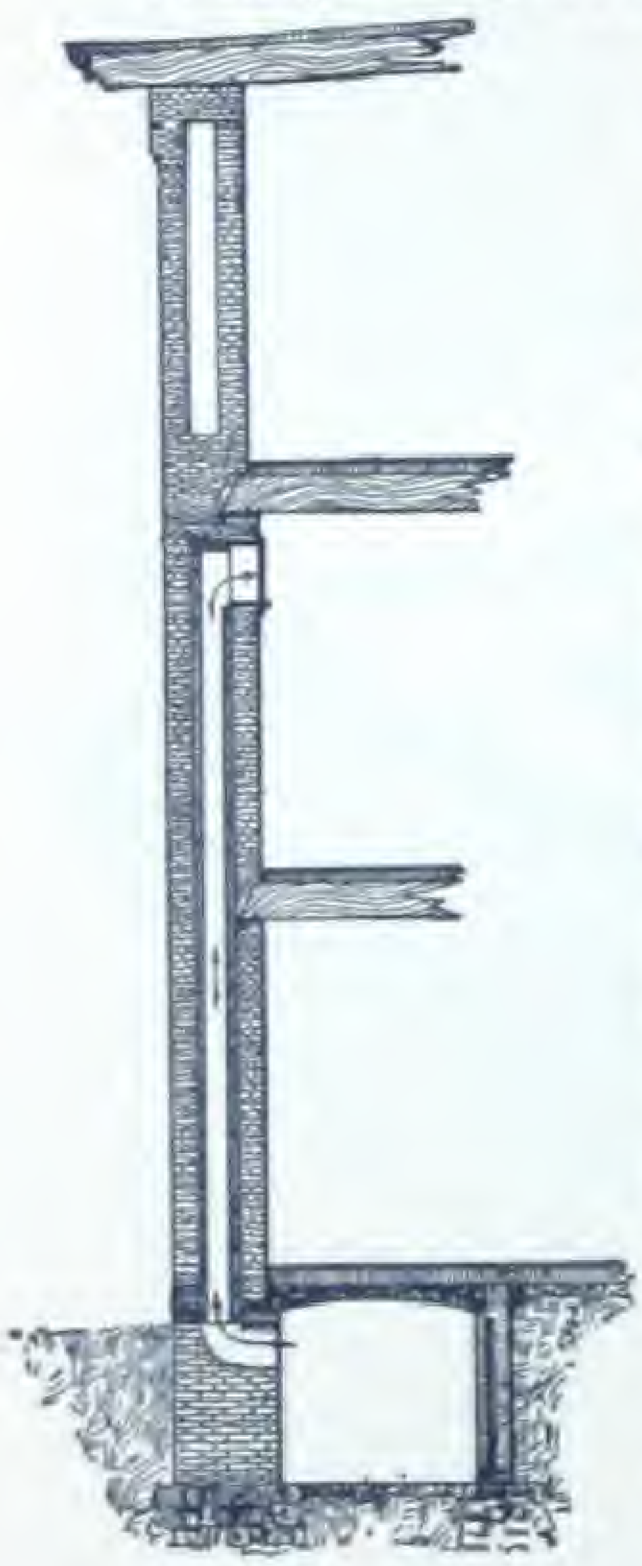


FIG. 70.

FIG. 71.

The apparatus, which is located about midway of the length of the mill, is of the duplex type, each fan being driven by its individual engine and the entire apparatus being located in an independent building. The absence of a basement under the mill is a sufficient explanation for this location. The underground ducts from the two fans unite before they pass beneath the mill wall and are here provided with a swinging damper, so arranged as to automatically regulate the pressure and volume of air discharged from each fan, and to further close immediately the duct from either fan in case it is shut down.

The duct extending from the apparatus toward the extreme right-hand end of the mill, as presented in the illustration, supplies the picker house, which is there located, and which, owing to the character of the process carried on within it, requires an exceptionally large volume of air for the double purpose of maintaining the temperature and making good the amount withdrawn by the picker fans.

# VENTILATION AND HEATING

ELECTRICITY IN TEXTILE MILLS. The presence of frictional electricity, generated by the motion of belts, pulleys, running stock and machinery, is a source not only of annoyance but of positive loss to mill owners. In carding and spinning particularly, electricity has the effect of causing a change of several numbers in the yarn and as much as three per cent. in the weight, weakening the yarn and causing it to snap and break; while the quality and width of woven goods is noticeably affected. Futile attempts have been made to conduct away this troublesome electricity, but all parts of a machine cannot be properly connected for the purpose, and a resulting residue of electricity is sure to make itself known. It is well understood that on moist days, by atmospheric conduction, the electricity escapes as fast as produced; while on dry days it is insulated in belt, machine and stock, and cannot escape into the air, for dry air is a poor, while moist air is a good, conductor of electricity. Moisture evidently plays a very important part in electrical troubles, and various attempts have been made to imitate the action of the moist atmosphere by admitting water to the mill rooms on dry days. The effect which moisture in the air has upon electrification in the rooms appears to be dependent upon the relative humidity in the mill rooms. The amount of moisture which the air will absorb depends upon, and increases with, its temperature. With the relative humidity above a certain per cent., no trouble is experienced; as this per cent. decreases, the electricity makes its appearance and grows more and more annoying.

A careful consideration of these statements will satisfactorily prove that the whole question of escaping from electrical trouble will be found in the matter of relative humidity. If there is sufficient moisture in the atmosphere, there is no trouble; if there is not sufficient moisture, electricity always appears.

As moisture depends upon the currents of air to distribute it, no better means can be found than the Sturtevant System for obtaining the required results. While doing efficiently its duty as a heating and ventilating medium, the air may be moistened to any desired degree by sprays or evaporating pans in the passages from the heater to the rooms. The exact humidity of the air may be noted by a hygrometer, and regulated to the closest degree. With an average temperature of 70° to 80° in the room, the per cent. of humidity need not exceed 70. This will insure a comfortable atmosphere, and will absolutely prevent the presence of any electricity. The mere benefit from this particular source will repay any enterprising owner for introduction, in these days when a saving of a fraction of a cent per yard is of vital importance. But with the additional advantage of an efficient heating and ventilating apparatus, controllable under all conditions, there can be no hesitation as to the desirability of the system.

# VENTILATION AND HEATING

## OFFICE AND MERCANTILE BUILDINGS.

In many respects the mercantile building does not differ greatly in its arrangement and requirements from the factory or shop. As a rule, large open floors exist, and the attendants are reasonably well separated. But to a greater extent than in the case of the factory, the side and, frequently, the rear walls are blank, because of abutting buildings; in fact, it is almost universally true that the store is most exposed upon the front; but show windows, with their inner sash or partitions, often serve as separate air spaces in a very beneficial manner to prevent the passage of heat.

In large wholesale houses there is seldom any obstruction above the level of the tables or counters; but, in some instances, shelving is carried well up to the ceiling. Evidently it is essential, in intelligently planning a heating and ventilating system for such a building, that the final internal arrangements be known. Owing to the independent rental of individual floors in a building of this character, it is frequently the case that any information regarding the arrangements within the room, or even the business to be pursued, cannot be ascertained in advance. Under such circumstances the general scheme can usually be laid out so as to provide for easy additions in the way of galvanized iron distributing pipe.

In the majority of cases overhead distribution is to be preferred, the air being discharged from flues in the inner walls toward the colder and exposed sides of the building. With a sufficient supply of air, ventilating flues are not necessary.

The office building is a distinctive feature of the modern city. Its numerous rooms, of various sizes, are all designed for a particular class of occupants. As a rule, the air space provided per occupant is large, so that a fulfilment by the Blower System of the requirements of heating is certain to incidently provide an ample supply of air per capita for all purposes of ventilation. The sedentary occupation of those for whom provision is made makes it necessary that a fairly high and equable temperature be maintained throughout the building.

It is evident that whatever the character of the heating and ventilating system, the control of the same for individual rooms must either be placed in the hands of the occupants thereof, or must be independently controlled for them, as by means of thermostats. Owing to the usual excess of air supply when heating is required, as well as to the complications incident to the introduction of a hot and cold system in a building of so many small rooms, this latter arrangement is seldom introduced. It is, however, usually a simple matter to apply it only to certain apartments in which the requirements demand it.

POPE MANUFACTURING CO., BOSTON, MASS. A modern mercantile building, exposed on all four sides, is presented in Fig. 72. Here, as may be noted, large open floors exist, unobstructed by partitions. The building, which is approximately square, is entered at the centre of the front, and connec-

FIG. 72. POPE MANUFACTURING CO., BOSTON, MASS.

tion with the various floors is secured by means of a staircase and elevator comprised in a brick well opposite the entrance, but well back toward the centre of the building. Upon the floors above the first there is, therefore, no encroachment upon the open character of the rooms, except that thus presented.

In the matter of heating and ventilating, this central well becomes of great importance, for it provides the opportunity for introducing flues to conduct the air to the various floors. The arrangement of flues is clearly presented in the illustration. At the back of the well are constructed two flues, one upon either side, reducing in area as they ascend and as air is discharged from them. The space between them is utilized for drawing a pure fresh air supply from the roof downward to the apparatus in the basement.

This apparatus is duplex in its character; the heater, consisting of a double group of sections, is placed between the fans in such a manner that the air from the supply flue first passes through it and then in equal volumes enters the two fans. Both fans are driven by a single double-enclosed upright engine placed upon the side of one fan, as shown, and driving the other by an extension of the shaft. The double engine makes high speed possible without attendant noise or excessive wear.

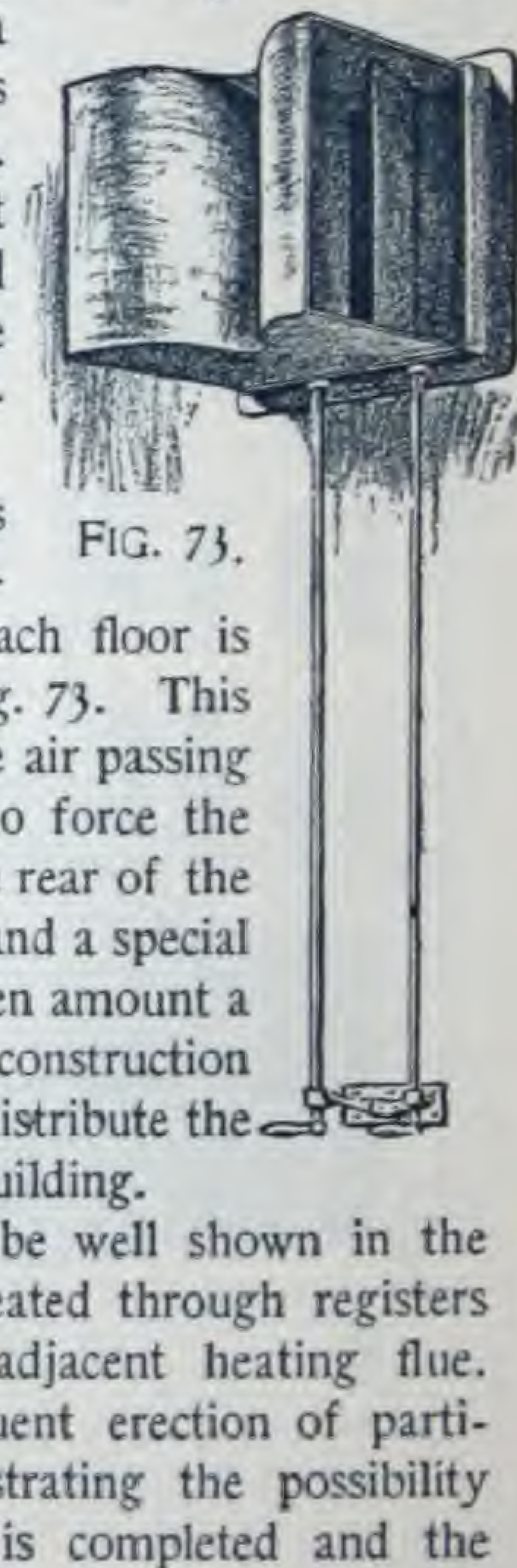


FIG. 73.

Each fan discharges horizontally at the top into its respective flue, whence the air passes upward for distribution throughout the building. About 9 feet above each floor is introduced a special form of damper, as illustrated in Fig. 73. This is so designed as to divide in the desired proportions the air passing through it, and to deflect its line of movement so as to force the greater part in nearly equal volumes to the front and the rear of the building. A rod, extending down from each damper, and a special friction device on the top, make adjustment to any given amount a simple matter. Two double deflecting dampers, of the construction here shown, one in each of the two flues, thus serve to distribute the warm air equably throughout each of the floors of the building.

Upon the second floor, in a position that cannot be well shown in the sketch, is a series of offices. These are individually heated through registers supplied from an overhead duct connecting with the adjacent heating flue. Rooms upon the fourth floor, formed by the subsequent erection of partitions, are also heated in a similar manner, thus illustrating the possibility of providing for such apartments after the building is completed and the system installed.

Simplicity and convenience are evident in this application of the Sturtevant System. Everything is compactly arranged, the apparatus and flues occupy the minimum of space, and distributing pipes are practically avoided.

AMERICAN BELL TELEPHONE CO., BOSTON, MASS. The general character and requirements of an office building have already been pointed out. In the case presented in Fig. 75 the structure illustrated is divided in its various floors into rooms of widely differing sizes, devoted to special lines of work, but practically all of a more or less clerical character. In the plan of the third floor, shown in Fig. 74, the general form of the building and the arrangement of the rooms is made evident.

In any office building or, in fact, in any structure containing numerous small rooms, the multiplicity of flues necessary to provide independent supply for each, together with the frequent diversity of arrangement on the various floors, practically forbids the construction of individual flues. Under certain circumstances the outer walls of a buildiug with symmetrical window arrangement may be utilized for the introduction of flues; but it is seldom that such opportunity is presented.

The only other resort, and that usually adopted for distributing the air supply, is that illustrated in this instance. At a convenient point, adjacent to

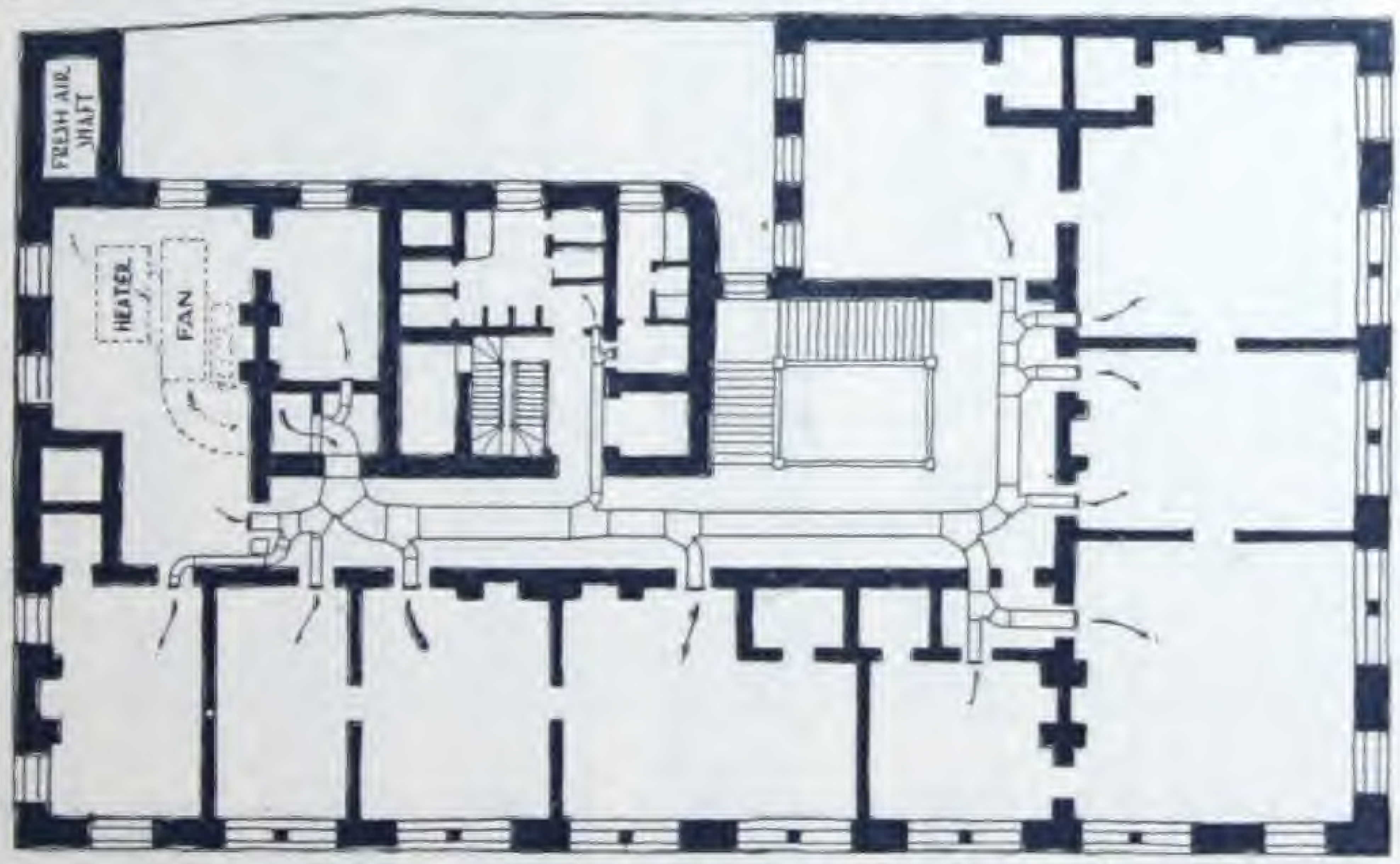



FIG. 74. AMERICAN BELL TELEPHONE CO., BOSTON, MASS., THIRD FLOOR PLAN.

the main corridor and as nearly central as possible, a vertical flue is provided. This need be merely of sufficient area to conduct the air at high velocity to the various floors; in fact, owing to the value of the space thus occupied, it is usual to make the velocity through this flue practically equal to that at which the air leaves the outlet of the fan.

FIG. 75. AMERICAN BELL TELEPHONE CO., BOSTON, MASS.

# VENTILATION AND HEATING

The floor heights being ample in this building there was introduced, just beneath the corridor ceiling upon each floor, a complete horizontal distributing system of galvanized iron pipe. This is all very clearly indicated in the plan view. Evidently such a system must, in the majority of cases, be rectangular in cross section, seldom exceeding 15 inches in depth. Taking its supply from the vertical flue, each one of these independent systems delivers air to all of the rooms upon its respective floor. It will be noted that numerous opportunities are offered, as at the connections to the flue, at the branch or a division near by, at the separate branches to the rooms and at the registers themselves, to sufficiently lower the velocity of the air below that existing in the flue, to secure its entry to the rooms with such relatively slow movement as to cause no draughts whatever.

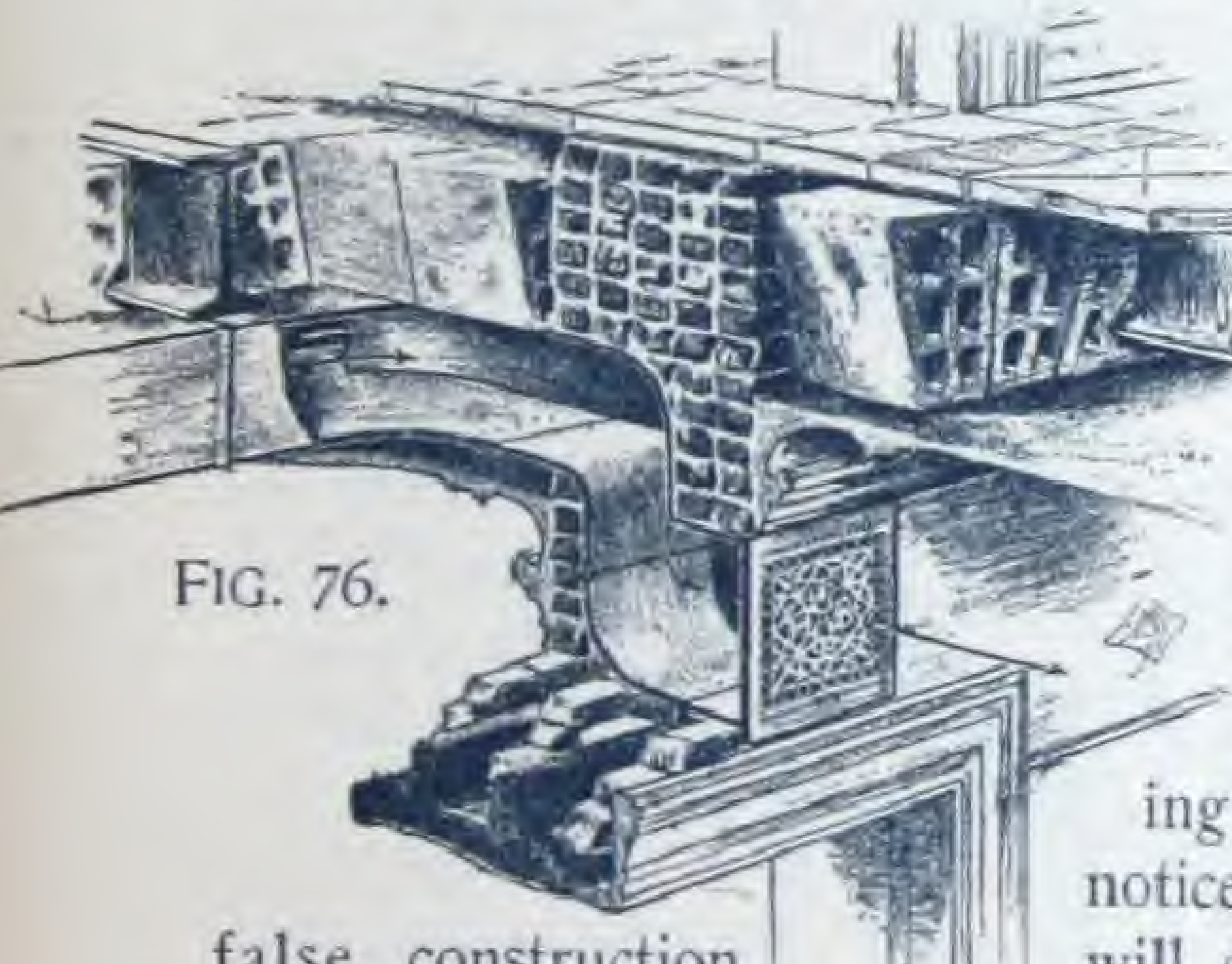


FIG. 76.

The finely-finished interior of such a building naturally demands that no piping should be exposed to view. It is customary, therefore, to finish down below the pipe and its branches the entire width of the corridor, making thereby a false ceiling, but little below that of the adjoining rooms, so slight, indeed, that it is seldom noticeable. Of course, the character of such false construction will depend upon the material of the building itself,—usually it is of wood or wire lath and plaster, with the necessary cross supports of wood or of iron.

In the case under consideration, the arrangement of the overhead duct and its branches is as indicated in Fig. 76. Here, fireproof construction is evident; but the building having a steel frame, it was a comparatively simple matter to introduce both the ducts and their connecting branches to the various rooms. In all cases the registers were, because of these conditions, placed close to the ceiling, and usually directly over the doors, as shown. The entire system, with the exception of the registers, was thus rendered entirely invisible.

The apparatus, shown in dotted lines in the plan, was placed in the basement in such a position as to enable it to take its fresh air supply through a shaft from above the roof-line. This shaft also offered an excellent opportunity for the introduction of special filters for removing from the air the minute particles of dust that are so much to be avoided in a large central telephone station such as exists upon the upper floor of this building.

## PRISONS.

The requirements of a building designed for the imprisonment of criminals are peculiar to itself. In the most advanced construction such a building includes, as its most important feature, the cell room or rooms variously arranged according to the ideas of those in authority, but, under all conditions, containing a series of small rooms for the separate confinement of the occupants.

Owing to the character of the inmates, it is obviously desirable that the heating and ventilating system should provide no advantageous opportunity for escape, while the occupation of the cells, during at least one-half of the twenty-four hours, requires that the maximum of air supply per occupant shall be provided. The separation of the prisoners, however, is such that the supply of air necessary to accomplish the heating under ordinary conditions is sufficient to meet all requirements per capita for the purposes of ventilation.

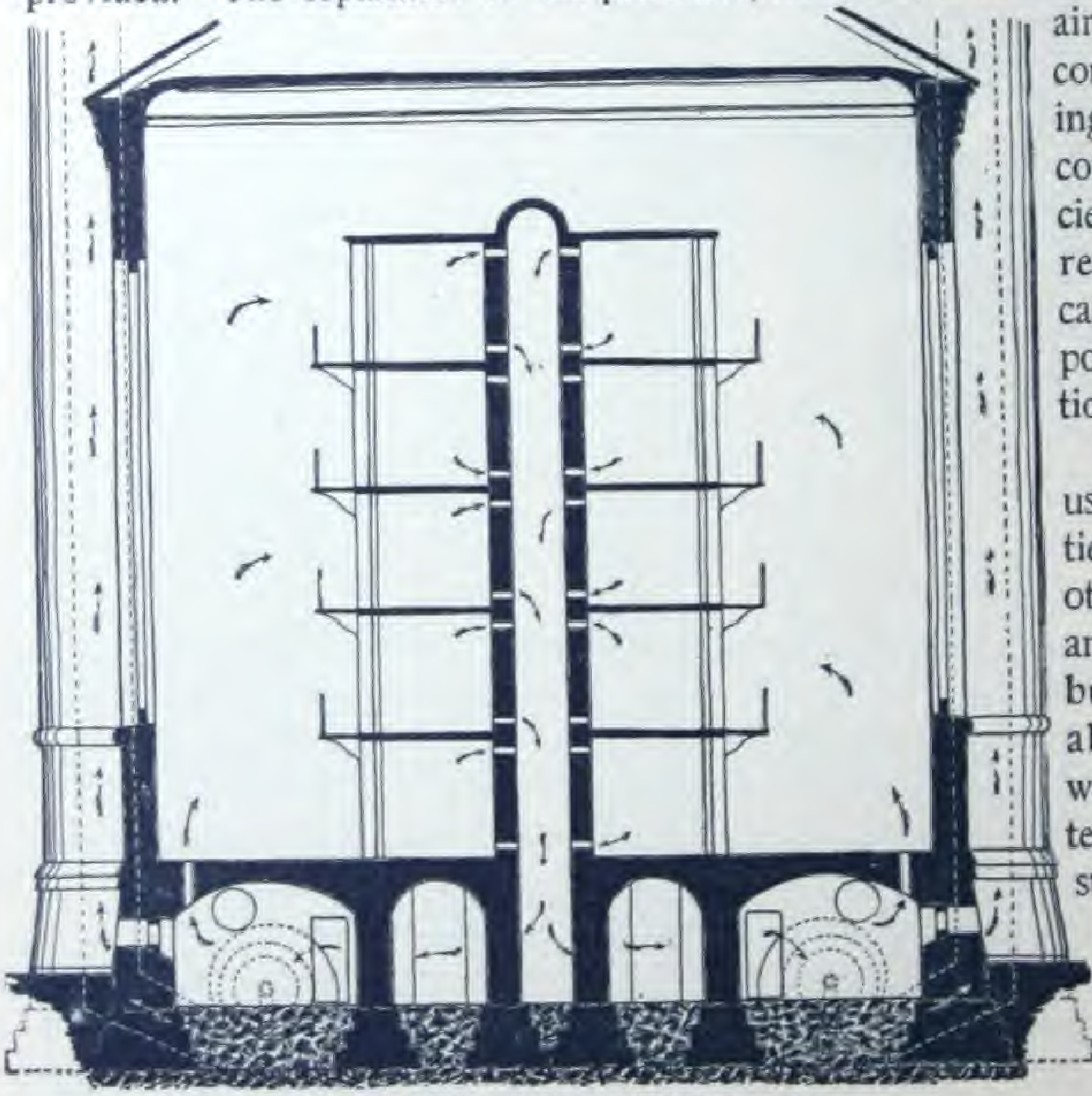


FIG. 77. SECTIONAL ELEVATION.

The cells are usually arranged in tiers, one above the other, either within an outer shell or building, or else abutting upon a well or corridor extending up several stories. To secure the requisite constant change of air, it must be evident, therefore, that mechanical means should be employed, and that both plenum and exhaust fans should be introduced to secure the necessary equality in distribution.

WESTERN STATE PENITENTIARY, ALLEGHENEY, PA. A model design for a cell room is shown by elevation and plan in Figs. 77 and 78. Within the outer shell, with its narrow and high-barred windows, are arranged four tiers of cells, each with its grated door opening upon an iron-floored gallery and facing the outside walls of the building, but about 15 feet therefrom. These tiers, arranged in two groups running lengthwise of the building, are separated at their backs, and the space thus found is utilized for ventilating purposes.

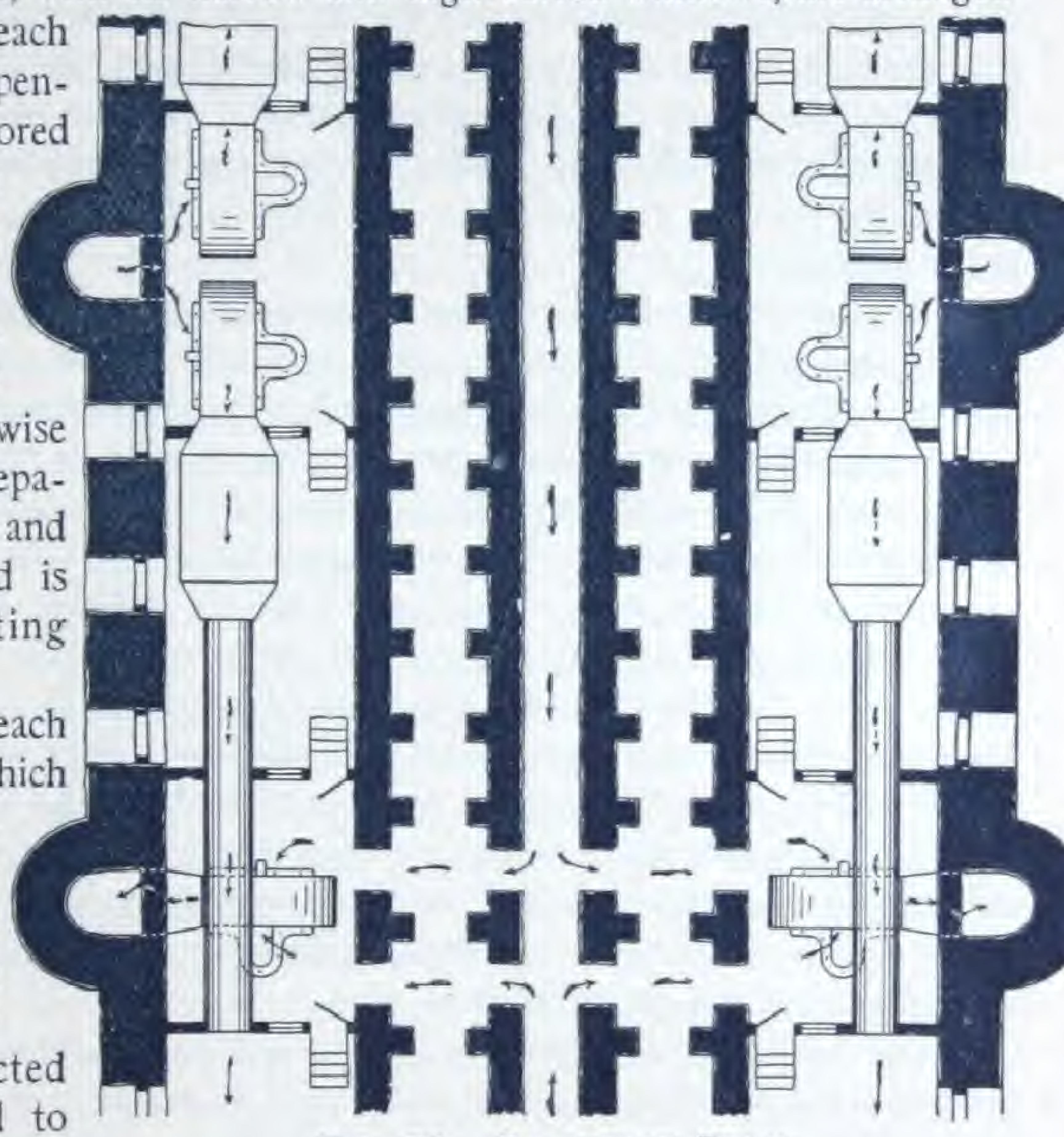


FIG. 78. BASEMENT PLAN.

In the basement of each of the cell houses, which radiate from the rotunda, are located four plenum heating apparatus, each consisting of a fan, driven by special direct-connected engine, and arranged to draw the air from above the roof through an exterior shaft and force it through the heater, whence it is discharged to the arched duct beneath the main floor. At regular intervals the heated air is discharged from this duct through floor openings to the room above.

From each cell at top and bottom the air, vitiated by its passage across the person of the occupant, is drawn down through the separating space at the back to the exhaust fans in the basement, which thus create a positive circulation and deliver the foul air above the roof.

All of these fans are over 12 feet in height, and are operated continuously. The official statement of those in charge shows, however, that since their original installation, over fifteen years ago, less than $25.00 has been expended upon them in the matter of repairs.

# VENTILATION AND HEATING

## SCHOOL BUILDINGS.

As a class no buildings are more important as regards their ventilation than those used for educational purposes. In such buildings are gathered, day after day, throughout the important years of their youth, the children who are to be the living forces of the coming generation. Present methods of instruction demand that they shall be confined within their respective rooms for four or five hours per day, and, with the exception of a short recess, for at least three hours consecutively.

The harm that might result from exposure to a vitiated atmosphere for three hours only once or twice a week, as would be the case in attendance upon church, entertainment or theatre, is evidently slight when compared with that which would follow from exposure under the continuous conditions of school life.

As compared with the home, the store, or the factory, the necessity of ventilation in the school is by far the most important, because of the comparatively close seating of the scholars. Even in the best schoolhouse design a space allowance of 250 cubic feet per scholar is usually considered to be the maximum. On the basis now generally accepted as the minimum for schoolhouse ventilation, viz., a supply of 30 cubic feet of air per minute per pupil, this initial volume of 250 cubic feet would evidently be sufficient for a period of only a little over eight minutes. That continuous renewal of this volume is an absolute necessity cannot possibly be questioned, when we consider not only the health of the children, but the mental vigor that should exist to secure the desired ends in educational matters.

The science of schoolhouse design and construction has been gradually crystallized into certain well-acknowledged principles. For middle and lower grade classes each room should be not far from 28 x 32 feet in floor plan and from 12 to 14 feet in height. Such a room is expected to accommodate from 50 to 55 scholars. Special attention is paid to the size and location of windows, so as to secure the proper degree of lighting and from the most desirable direction. As a rule, the rooms of such a building are symmetrically grouped, and it is seldom that the height of the structure is over two stories with basement, except in the heart of a city where land is exceedingly valuable. In the modern eight-room building, as is also the case where the the number of rooms is greater, it is customary to provide an assembly hall upon the upper floor. The basement is also frequently utilized for instruction in manual training. High school, academy and college buildings, with their provisions for recitation and lecture rooms, laboratories, libraries, and the like, are usually much more

diversified in their construction, so that symmetry of arrangement upon the various floors is made less likely to be found, thereby obviously increasing the difficulty of introducing vertical flues in a simple manner. As a rule, however, such buildings are of brick, with internal partitions of the same material. This construction readily permits of the introduction of both heating and ventilating flues in the most advantageous position, namely, in the inner walls. A basement of ample height also presents an excellent opportunity for the location of the apparatus.

From previous remarks it must be evident that the most desirable method of heating and ventilating an ordinary schoolhouse must be by the introduction of the warm air through registers in the inner walls and at some eight feet above the floor. Ventilating flues in the same walls, with openings near the floor, present the means for inducing the most complete distribution of air throughout the room and for its removal when its intended work is done.

Care should be exercised in the selection of the location for the apparatus in the basement. Its position should be such as to require the minimum of distributing ducts for connection to the flues; while, incidentally, it is expedient that it be placed, if possible, under a corridor or other apartment than a schoolroom, in order to avoid even the possibility of noise or vibration when operated at full speed. Unless supplementary coils are placed at the bases of the flues, the apparatus for a school building should always be of the hot and cold type, in order that the temperature of any given room may be adequately regulated without reference to that of others in the building.

As the height of the basement usually permits of such an arrangement, it is customary to construct the system of ducts of galvanized iron, and carry them overhead close up to the ceiling. They can, however, be easily introduced in the form of brick conduits underground, and where the hot and cold method is adopted the mixing dampers may also be placed underground, at the bases of the various flues, and arranged to be operated by thermostat, or by chain, from their respective rooms.

The plenum system may be almost universally depended upon to secure the proper ventilation of a school building without the accessory of an exhaust fan, although the latter can be readily introduced, if the complexity of the building and the vitiating effects of chemical and other laboratories demand it. Two of the principal methods employed in the introduction of the Sturtevant System in school buildings are illustrated and described in the succeeding pages.

"The Ventilation and Heating of School Buildings" is exhaustively treated in a special catalogue under this title, which will be sent upon application.

AGASSIZ SCHOOL, BOSTON, MASS. The general characteristics of a modern fourteen-room school building with large assembly hall, designed for a grammar grade, are well presented in Figs. 82, 83 and 84, as is also the application of the hot and cold double duct system of heating and ventilation. In the basement, midway of the length of the building, is located the apparatus, consisting of two fans, driven by a horizontal independent engine and arranged to force air through, or by-pass it above, the heater.

From the end of the heater extend two systems of overhead galvanized iron ducts, both rectangular in section, the upper conveying cold, and the lower hot, air. Both of these ducts connect with the bases of all of the schoolroom flues, there being introduced at each point of connection a Sturtevant mixing damper of the form already illustrated in Fig. 11. In addition, air is discharged from the hot-air duct to floor registers in the first-floor corridor and in each of the cloak-rooms on the various floors.

The compact and symmetrical arrangement of the flues in the inner walls is rendered evident in Fig. 82, wherein is also shown the location of the boilers and smoke flue. Passing up these flues, which are of the construction shown on the left of Fig. 84, the warm air enters each room through a grated opening about eight feet above the floor. The appearance and location of these openings is clearly indicated in Fig. 79, the grating being made of one-eighth inch square wire with one-inch mesh. Such a grating or screen presents greater free area for given outside dimensions of opening and at less cost than a register face.

FIG. 79.

In the building under consideration the regulation of temperature was placed in the hands of the occupants. Each mixing damper was provided with a strong chain, which passed up the flue to a point below the screen, where it was carried over a pulley and through the wall just below the chalk rail. A dial, with inscriptions and arrows, as shown in Fig. 80, served as an indication of the

required direction of movement of the chain to secure either hot or cold air, while a pin on its front furnished a simple means of locking the chain when once in position. This system could have been arranged equally well for the regulation of temperature entirely by means of thermostats, the damper being fitted up either as shown in Fig. 13 or in Fig. 14.

Each of the vent flues, in which the outlet screens are located near the floor, was provided with a special shut-off damper, placed above this opening and arranged to be operated by chain from the basement. The escape of air from the rooms could thus be conveniently regulated by the janitor according to the external conditions; for on extremely cold days the natural discharge of air through these flues would frequently be in excess of the requirements. The arrangement further provided the simplest means for preventing all escape of air from the building during the night and while heating up in the morning. All of the ventilating flues discharge above the roof through the brick stacks.

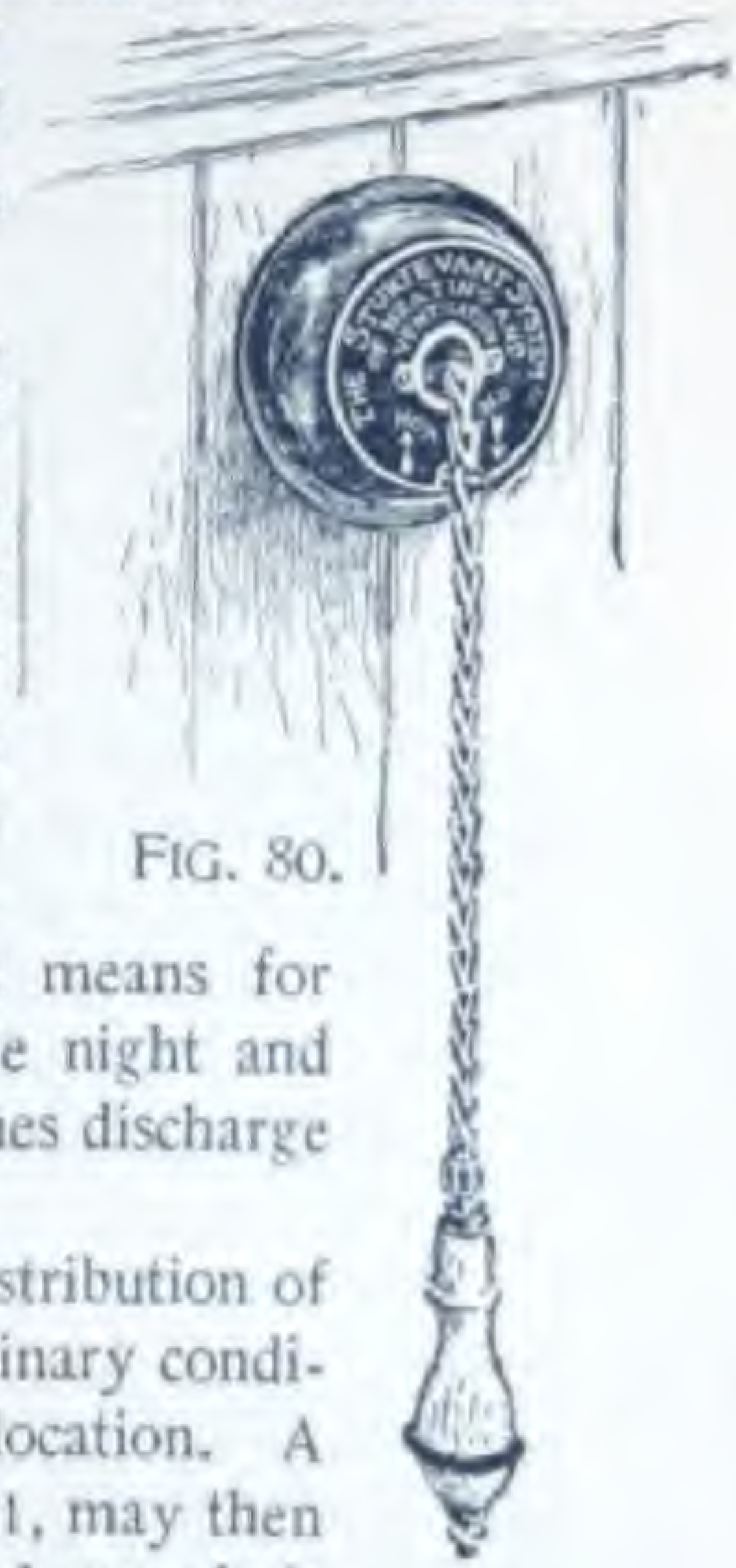


FIG. 80.

It is sometimes desirable to secure a more complete distribution of the air throughout the room than would result under ordinary conditions with an opening in some enforced location. A diffuser, of the type shown in Fig. 81, may then be employed to break up the volume of air as it leaves the opening and produce separate currents moving in diverging directions.

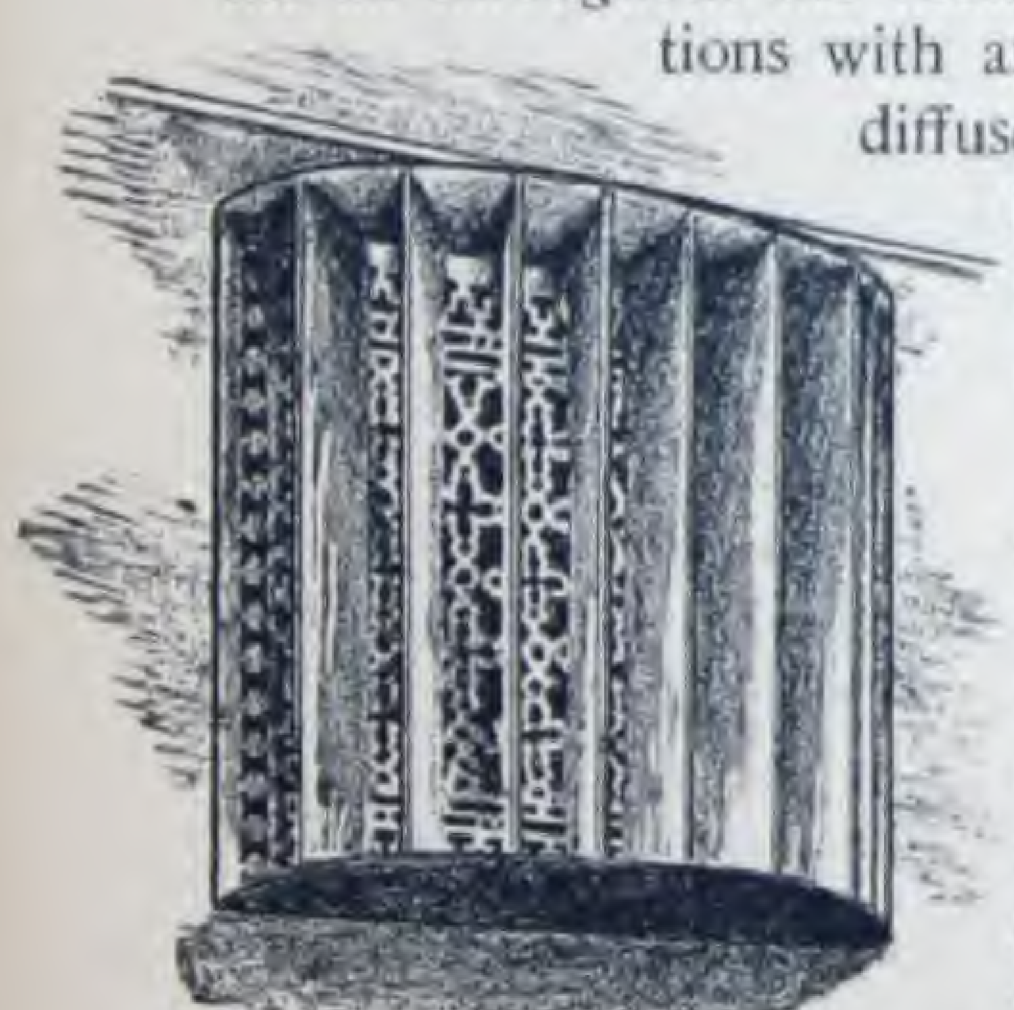


FIG. 81.

As the primary adjustment of the system should provide for the delivery of the proper amount of air to each room, it is usually undesirable to provide any means whereby the occupants of the rooms can readily reduce its volume. Such shut-off dampers as may be introduced in the system are, therefore, arranged to be operated by the janitor. Ventilation of the sanitaries in the basement is secured during the operation of the boiler by the aspirating effect of the boiler flue, around which passes the air direct from the closets, whence it is conducted by underground ducts. At other times this ventilation is maintained by the heat from a special stove placed beneath the smoke flue.

MENOMINEE HIGH SCHOOL, MENOMINEE, MICH. While there is in various school buildings comparatively little divergence from the general scheme of air admission and removal previously described, there is usually presented considerable opportunity for variety in the arrangement of the apparatus and distributing ducts in the basement. A scheme differing in many particulars from that just illustrated is shown in Fig. 85.

Here the fan is of the three-quarter housing type, with large outlet. The engine is independent, and drives the fan by belt. Placed opposite two of the basement windows are two tempering coils, arranged to utilize the exhaust steam from the engine, and designed to simply take the chill off of the air.

Enclosed in a brick chamber in front of the fan are two groups of heater sections set high above the floor, so that the air discharged from the fan may pass either beneath or through them. From the end of this air chamber extends a system of individual overhead rectangular galvanized iron pipes, one for each of the vertical heating flues. Each pipe is so arranged at its connection with the air chamber that, according as a damper is adjusted, it may draw its air from the supply that has passed through the heater or from the space beneath, to which is delivered the cooler air.

Each one of the individual dampers is arranged to be operated by a thermostat, which acts in harmony with the changes in temperature of the room with which the pipe and its respective flue connect. By this thermostatic action warm or cool air is delivered to the room according to its requirements, and it is a simple matter to maintain the room temperature within a range of two degrees. The advantageous features of this general design lie principally in the assembling of the thermostats in the air chamber and in the avoidance of a double system of ducts.

The ventilation of the sanitaries is made positive and ample by providing a small exhaust fan, driven by the fan engine, and arranging a system of underground ducts through which the foul air is drawn to the fan and thence forced to the space around the boiler stack. In these sanitaries the heating is effected by overhead steam coils without direct supply of air. The exhaust ventilation, however, is made so strong, aided by the plenum effect within the rest of the building, that all leakage is inward and all possibility of the escape of foul odors to other parts of the building is avoided.

When the construction of the basement will permit, the warm air is sometimes discharged into a large chamber occupying the central portion of the basement, whence it escapes through openings and short pipes to the various flues, there to be heated by supplementary coils under the control of thermostats.

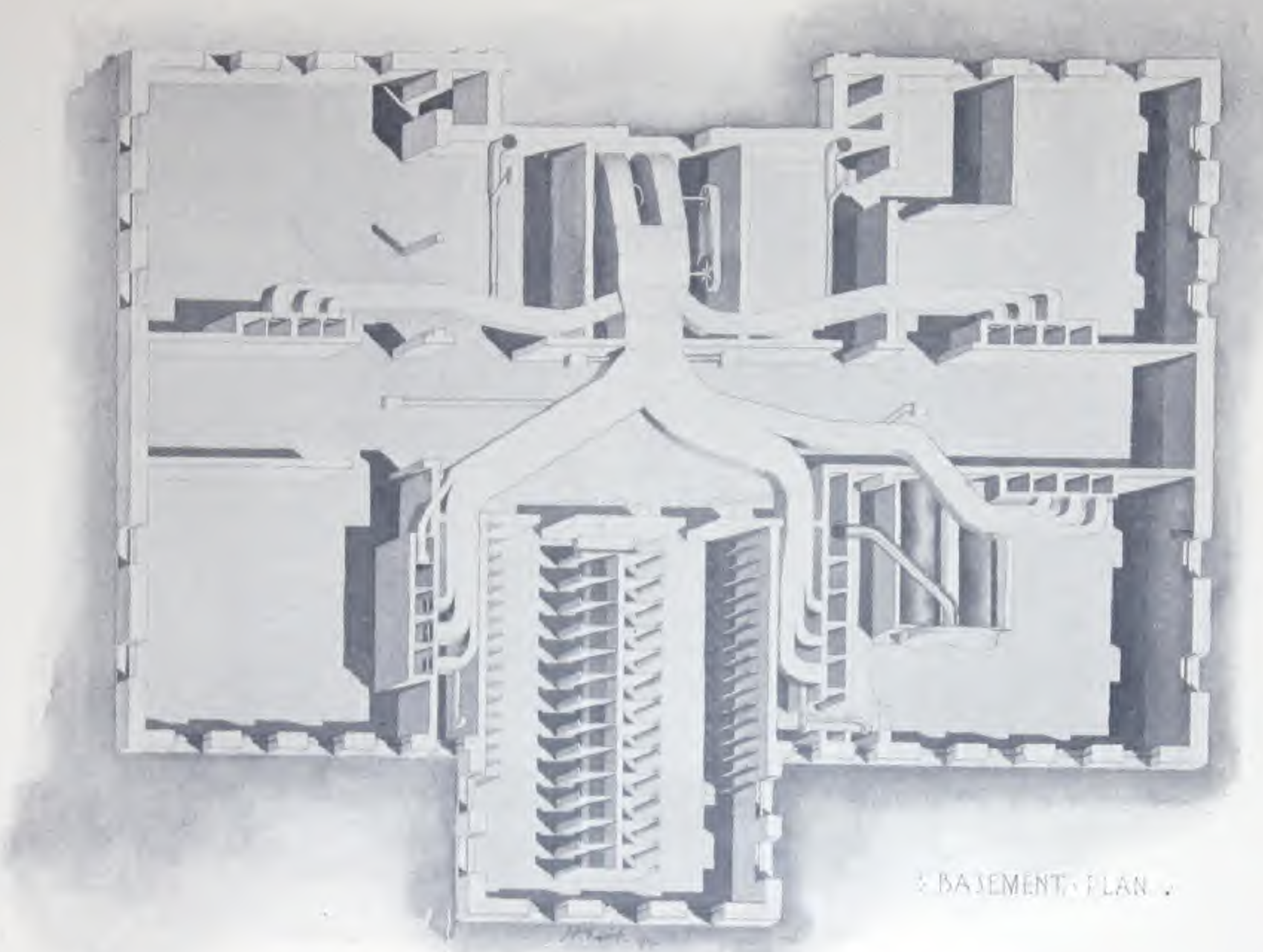



FIG. 82. AGASSIZ SCHOOL, BOSTON, MASS.

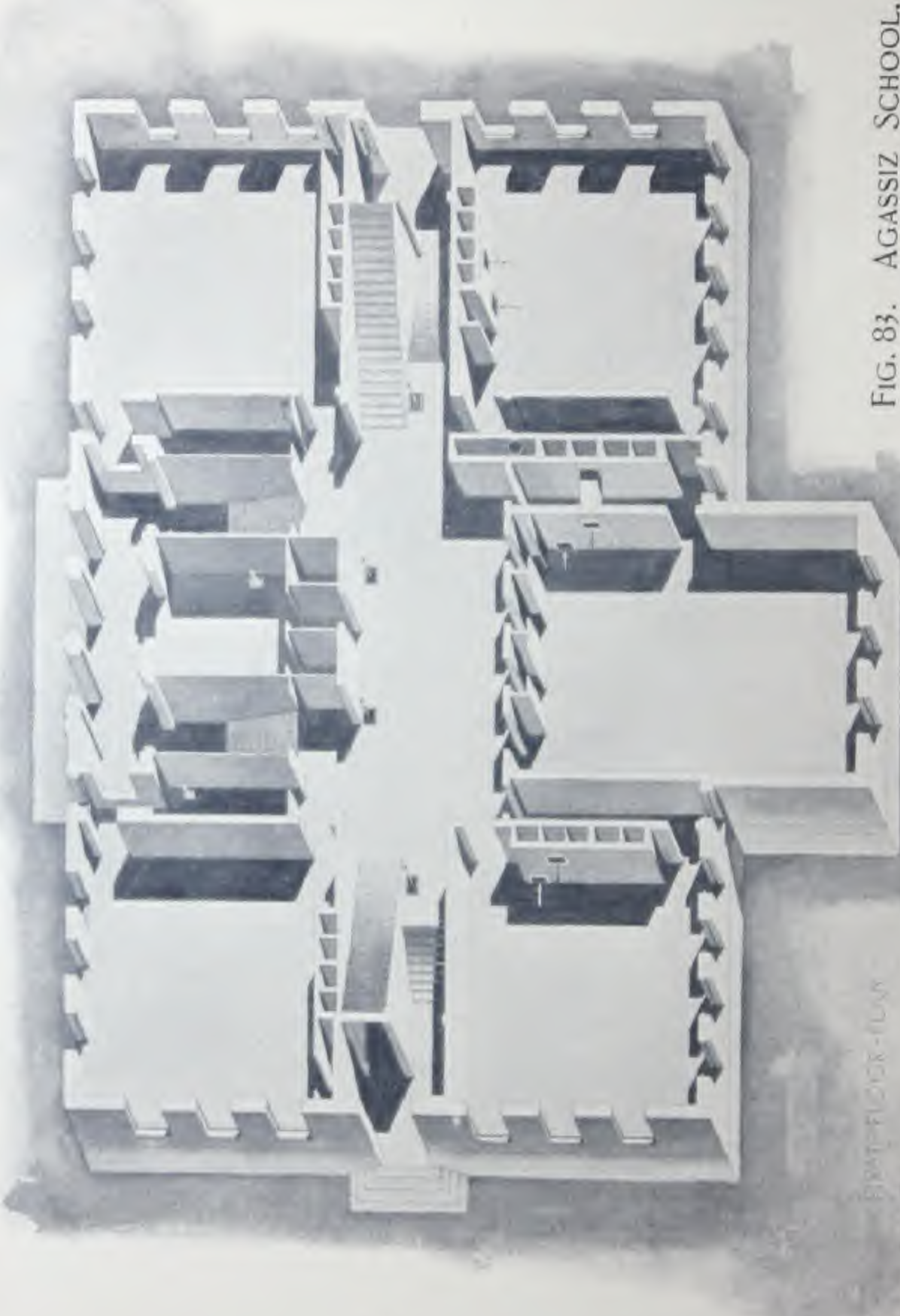



FIG. 83. AGASSIZ SCHOOL, BOSTON, MASS.


FIG. 84. AGASSIZ SCHOOL, BOSTON, MASS.

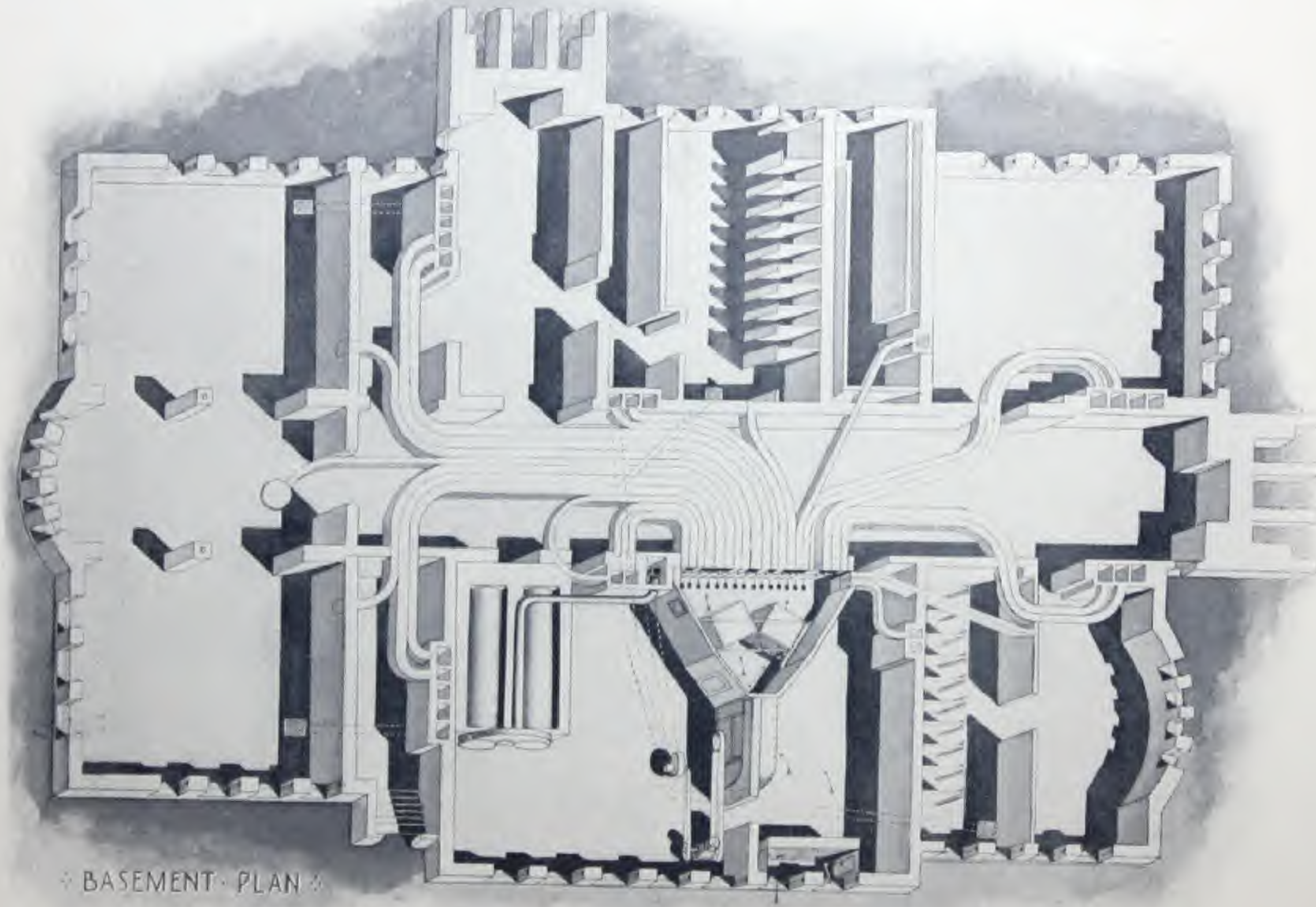



FIG. 85. MENOMINEE HIGH SCHOOL, MENOMINEE, MICH.

# VENTILATION AND HEATING

## HOSPITALS AND ASYLUMS.

The evidences of insufficent ventilation are nowhere more pronounced than in buildings devoted to the use of the sick and diseased. Constitutions already weakened are very quickly rendered still more susceptible to the further inroads of disease by exposure to a vitiated atmosphere. The marked improvement in the healthfulness of such buildings where good ventilation obtains was pertinently shown in the opening chapter.

Because of the more perceptible benefits of pure air in buildings of this character, they have long been the subject of thoughtful study as to the best means to secure the desired ends. Long before efficient systems of ventilation were applied to other buildings, the hospitals of this country and of Europe were equipped with ventilating devices that in their day were far in advance of those introduced in any other structures.

In no buildings should the ventilation be more carefully considered in the development of the original plans than in those of the class under consideration. The intended use of each room must be known, the arrangement of beds in the wards should be determined, and even the character of the diseases which are to be treated in the various wards should by no means be overlooked.

In the thoroughly-equipped hospital of the present day there is always special and separate provision for contagious diseases, almost universally in independent buildings. Evidently the maximum ventilation is required under such conditions. The 30 cubic feet per person, deemed sufficient in the school and the hall of audience, becomes utterly inadequate when the atmosphere is laden with contagious disease germs. From a theoretical standpoint too much air cannot be supplied under these conditions; in practice, however, it frequently runs up to 100 cubic feet per minute and over.

To secure the positive supply of such an amount naturally demands positive and mechanical means. In the hospital of moderate size the plenum system will meet all requirements, but under certain circumstances, in more complicated structures, it becomes desirable to assist its action by exhaust fans.

In the majority of cases the occupants of asylums are supposed to be in a reasonably healthy condition, so far as the general functions of the body are concerned. The air supply per capita, therefore, usually need be merely that provided for other classes of buildings devoted to similar uses, where the occupants gather in certain rooms, or out of doors, during the day and return to their dormitories, or individual sleeping rooms, for the night. Where the violently insane are confined in individual cells the same methods apply as in a prison.

WALTHAM HOSPITAL, WALTHAM, MASS. In its application to a city hospital of moderate size the Sturtevant System is shown in Fig. 86. The wing upon the right in the illustration is divided into numerous small wards and nurses' rooms, so that the method of distribution becomes similar to that provided for an office building or a dwelling. Owing to the fact that the building was of so-called mill construction, with no heavy internal partition walls, it was necessary to supply practically all of the fresh air and remove the foul air through flues built into the exterior brick walls. The general arrangement of these flues upon one end of the building is indicated.

In the basement is located a draw-through apparatus, provided with engine


FIG. 86. WALTHAM HOSPITAL, WALTHAM, MASS.

for motive power, when steam is necessary for the heating, and with electric motor for propelling the fan when the boiler is not in operation. An overhead system of galvanized iron ducts in the basement serves to distribute the air from the apparatus to the bases of the various flues.

In the other wing are located two wards, one upon either floor, and both of considerable size. These are heated from overhead outlets, as indicated. The air is forced toward the end of the room farthest from these outlets, being generally diffused in its passage and finally escaping through registers at floor level and nearly beneath the supply openings. Thence the air is discharged above the roof. In more complicated arrangements, and particularly in contagious wards, the system may be arranged to furnish practically every bed with an independent supply. But considering the rapidity with which the air thus supplied diffuses itself in the surrounding atmosphere, such arrangements are not as efficacious as would at first appear.

The operating room of a hospital always requires an extremely high temperature to be secured at almost a moment's notice when an accident case is suddenly brought in. In the building under consideration provision was made for the supply of a large volume of hot air to this room, whereby its temperature could be suddenly raised to, and maintained at, the desired degree. Incidentally this large volume of air, of course, provided the maximum of ventilation at a time when fresh air is very desirable.

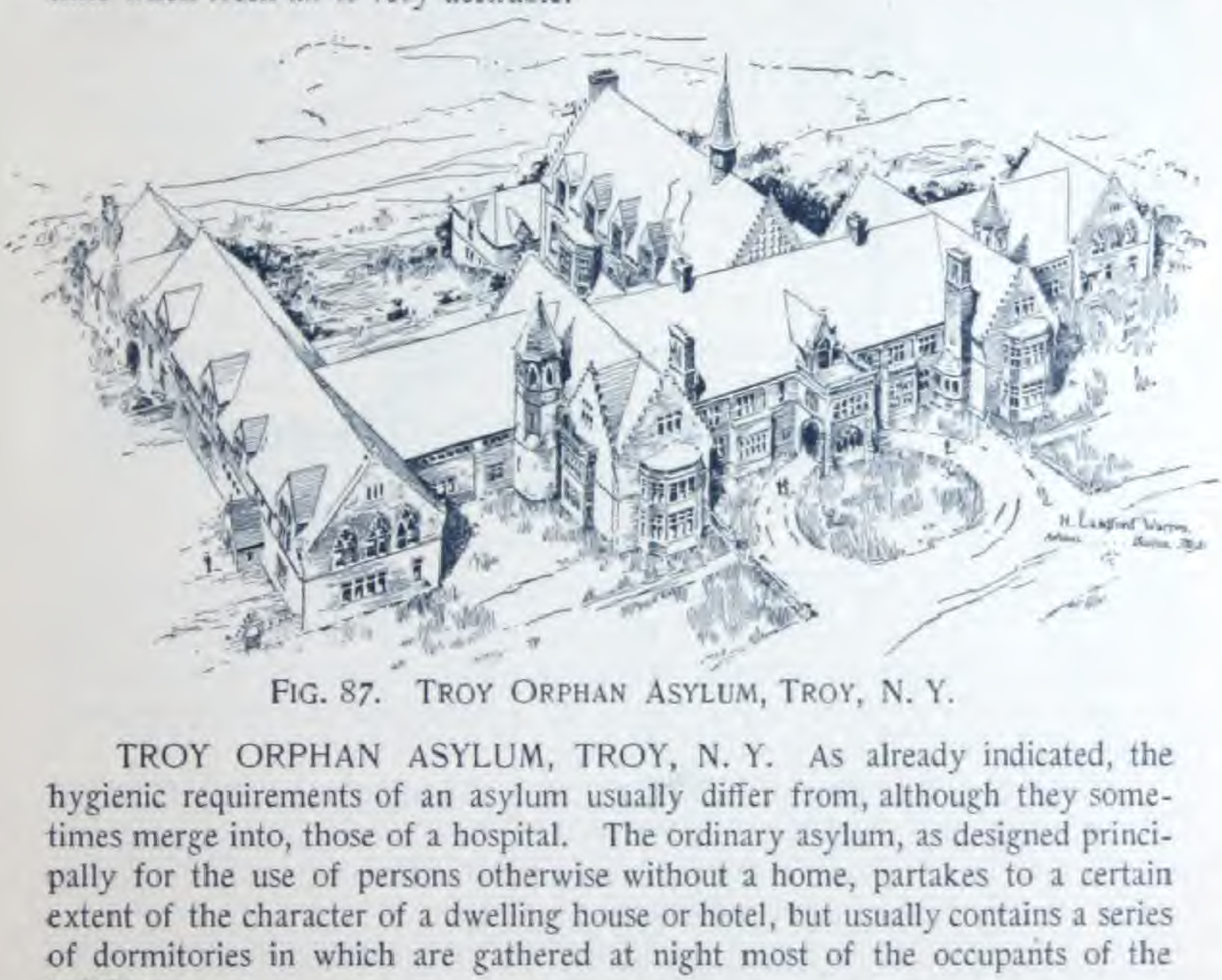


FIG. 87. TROY ORPHAN ASYLUM, TROY, N. Y.

TROY ORPHAN ASYLUM, TROY, N. Y. As already indicated, the hygienic requirements of an asylum usually differ from, although they sometimes merge into, those of a hospital. The ordinary asylum, as designed principally for the use of persons otherwise without a home, partakes to a certain extent of the character of a dwelling house or hotel, but usually contains a series of dormitories in which are gathered at night most of the occupants of the building.

A typical building or series of buildings of this class is illustrated in Fig. 87. Here it is evident that an extended distributing system is necessary, and it may even be questioned whether a single apparatus will be most satisfactory for the purpose. As will be noted in Fig. 88, the problem, after all, resolves itself into the question as to whether the apparatus shall be placed in the building itself or in the boiler and power house at the rear.

Here was a case where the matter of attention by the engineer entered as an important factor. His greatest efficiency could, of course, be best secured by massing the apparatus under his control. Hence the location of the heating and ventilating apparatus in the boiler house. Thence the air, delivered to an underground brick duct by a three-quarter housing fan, passes beneath the centre building, where its volume is divided, a portion passing to each wing through galvanized iron pipes, which connect with the ends of the ducts, and, rising, are carried overhead in the basement.

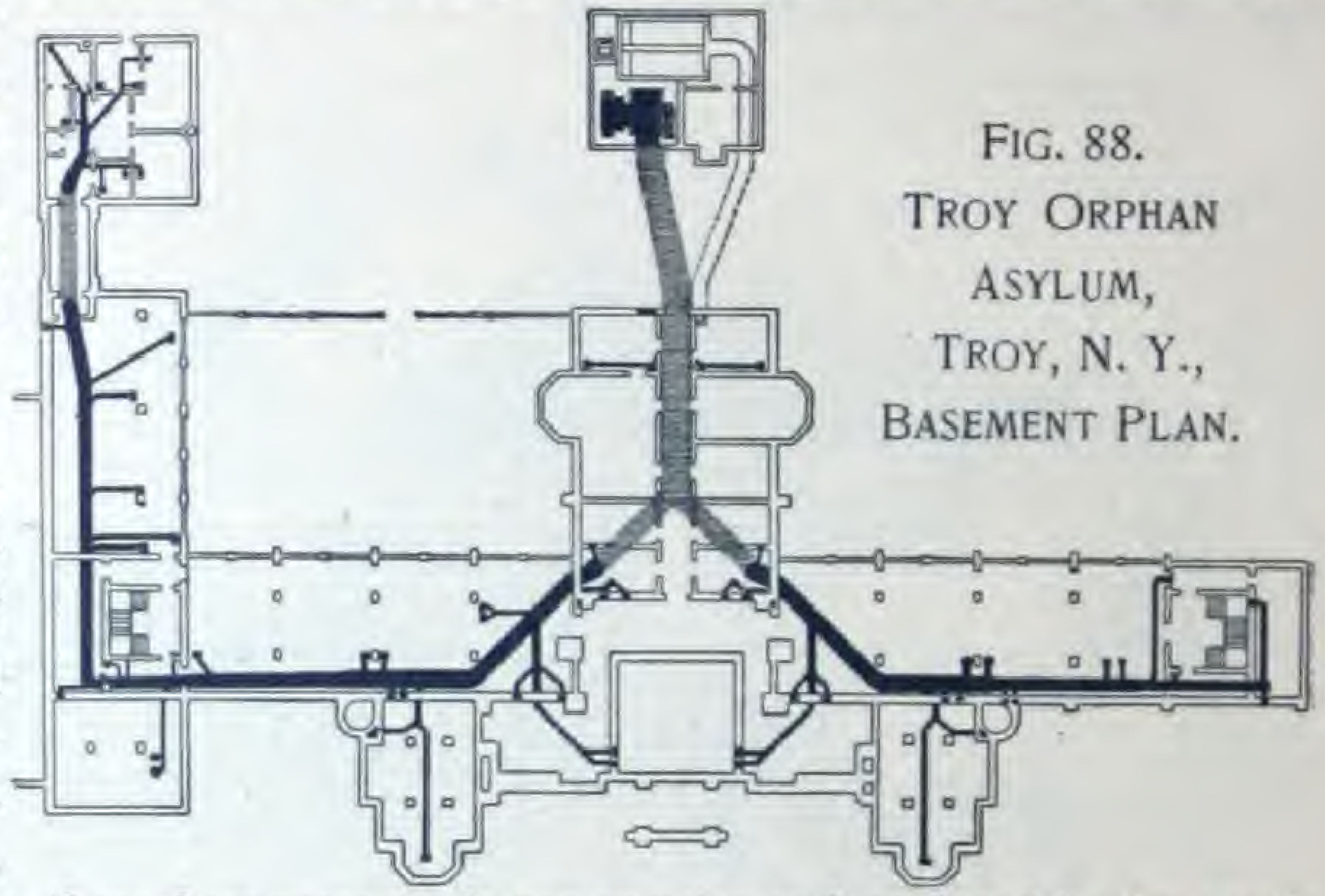


FIG. 88. TROY ORPHAN ASYLUM, TROY, N. Y., BASEMENT PLAN.

The internal partitions of the building being principally of wood, the vertical flues were constructed of galvanized iron. Wherever possible, these flues were made rectangular and enclosed in the partitions, but in the majority of cases they had to be carried up outside of the partitions, and false work breasted out around them to give the proper finish. In other cases they were carried up in the corners and the finish extended diagonally across the corner outside of them.

From these flues the air is admitted at the usual height above the floor, and allowed to escape through ventilating registers at floor level, whence it passes up to the attic space. Roof ventilators and louvred windows provide an opportunity for it to finally escape to the outer atmosphere.

As the rooms are designed for various uses, and are diversified in their size and arrangement, the methods of distribution were adopted to suit. The system throughout was designed to supply hot air only, and serves its purpose well, as the air space per occupant is such that for the mere purposes of heating the air supply per capita is more than ample to meet the requirements of ventilation. It must be evident, however, that a hot and cold system, with the requisite double ducts and mixing dampers, could have been introduced if it had been deemed necessary.

# VENTILATION AND HEATING

## PUBLIC BUILDINGS AND HALLS OF AUDIENCE.

Although in its broadest sense the expression "Public Building" evidently includes a great variety of structures, yet, as ordinarily employed, the term generally refers to town and city halls, State Houses, court buildings, and to the buildings used for the meetings of a National assembly. In all the buildings included in this class there is a similarity in design and construction, such that they may be grouped together when considering their ventilation and heating.

The characteristics of such a building are, one or more large rooms or halls, used as assembling places, and numerous smaller apartments serving practically the same purposes as similar rooms in an office building, the application of the Sturtevant System to which has already been discussed. The same principles and methods hold with similar construction in a public building.

The assembly rooms, however, offer a somewhat new problem in heating and ventilation. In the well-equipped modern legislative hall the seats are usually arranged in the form of an amphitheatre, upon levels successively rising toward the walls most distant from the presiding officer. The presence of individual desks enforces the separation of the occupants much as in a schoolroom, so that the initial air space per capita is usually large. But unlike a schoolroom, the legislative hall is frequently occupied for many hours in succession, and often during the night, when the effect of the lighting medium has to considered, while the number of persons present is constantly changing and sometimes suddenly augmented by the crowding of the galleries.

Add to these conditions the fact that even in a State Legislature there is great diversity in the age, health and home surroundings of the members, while in a National assembly in a country like our own there is, in addition, the most radical difference in climate between the parts of the country from which they come, and it is obvious beyond all question that no more difficult problem in heating and ventilation can be considered. As a rule, the treatment of such an apartment should be on the same lines as that of a theatre, with well-distributed supply, as indicated in subsequent illustrations and description.

The ordinary hall of audience, with level floor, often with gallery, but seldom with more than one, presents conditions different from both the legislative hall and the theatre. The frequent location of such a hall in the upper floor of a building, with numerous offices and smaller rooms beneath, has a certain influence upon the possible methods of heating and ventilation.

HERSEY MEMORIAL BUILDING, BANGOR, ME. Although not so indicated by its title, the building illustrated in Fig. 89 is a municipal building, devoted to the uses of a city hall, and provided, in its upper story, with a large audience hall for general public and private uses. As the lower portion of the building is subdivided into comparatively small rooms, and their treatment is substantially the same as in an ordinary office building, it has been the endeavor to present in the cut only the method of application of the Sturtevant System to the hall itself. As will be noted, this hall, with its stage and galleries, occupies the

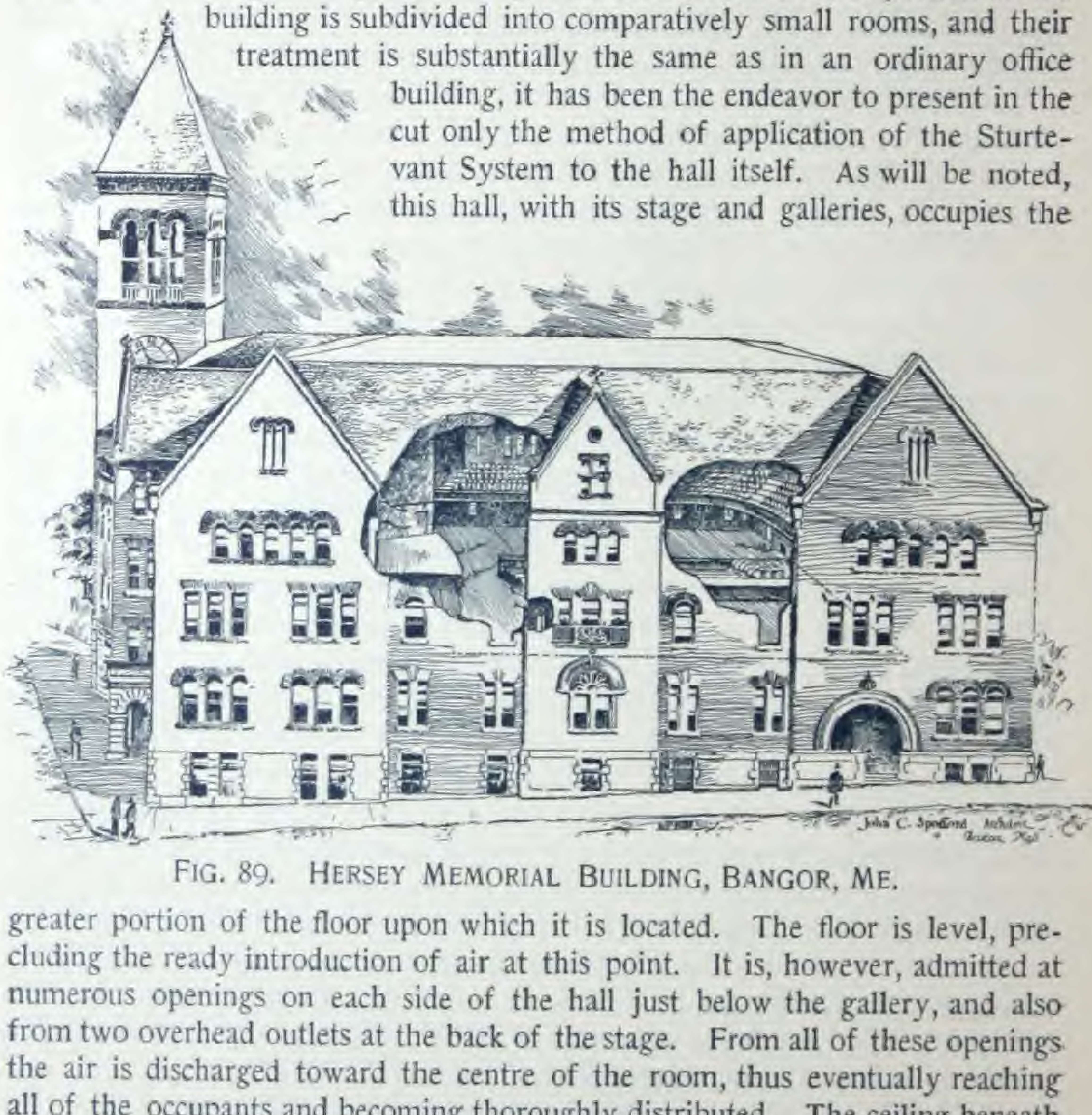


FIG. 89. HERSEY MEMORIAL BUILDING, BANGOR, ME.

greater portion of the floor upon which it is located. The floor is level, precluding the ready introduction of air at this point. It is, however, admitted at numerous openings on each side of the hall just below the gallery, and also from two overhead outlets at the back of the stage. From all of these openings the air is discharged toward the centre of the room, thus eventually reaching all of the occupants and becoming thoroughly distributed. The ceiling beneath the balcony presents a most excellent surface to aid in forcing the greater part the air toward the centre. But in its passage a certain portion falls and supplies those seated at floor level, while a sufficient volume curls up over the gallery front to supply its occupants.

Ventilation takes place at numerous points, the larger volume passing in beneath the stage through its grated front to a large ventilating flue at its back, and thence into the roof space and the tower. Ventilating registers, placed against the walls at floor level, also assist in the removal of foul air. Unless actual supply through the floor is possible in a hall of audience (under which conditions ceiling ventilation would be feasible), it should be the aim to admit the air horizontally at as low a level as possible, and by means of ventilation at a still lower level, to prevent the overheating of the galleries.

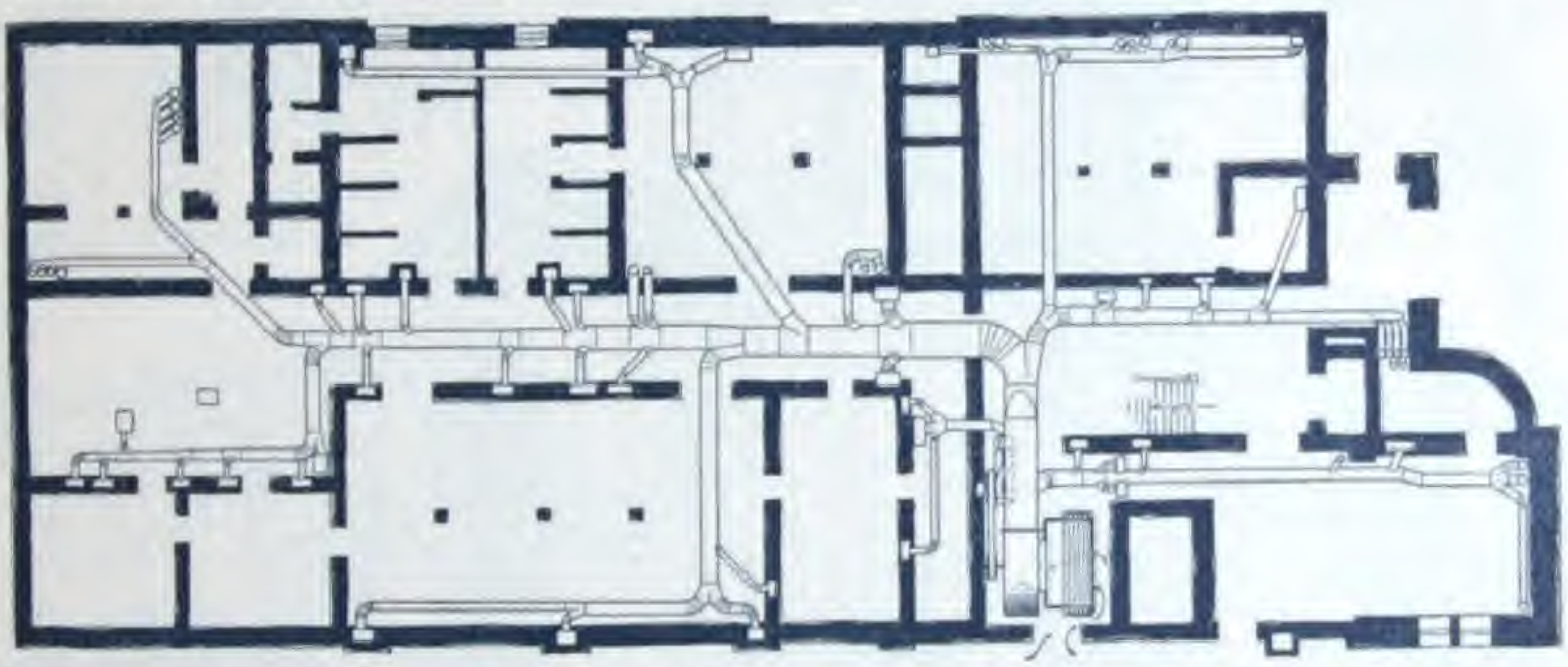


FIG. 90. HERSEY MEMORIAL BUILDING, BANGOR, ME., BASEMENT PLAN.

The general arrangement of the apparatus and the scheme of air distribution is presented in Fig. 90. The apparatus is placed near a window, whence its supply of fresh air is drawn. The heated air passes through an extended system of overhead galvanized iron ducts in the basement to the bases of the various flues. Most of those for the audience hall are located in the outer walls, while those for the lower floor are, to a considerable extent, formed in the interior partition walls.

A special small fan driven by water motor, but not shown in the plan, was also installed for the purpose of rendering positive the ventilation of the toilet rooms, from which it withdraws a large and constant volume.

In a building of this character, in which it may be known that almost without exception the hall is to be used in the evening, while the majority of the other rooms in the building are vacant, it is sometimes possible to arrange to divert some of the air from the office portion and throw it into the hall, but the possibilities of the coincident use of all the rooms usually render such an arrangment of doubtful utility.

NEW HAMPSHIRE STATE LIBRARY AND COURT HOUSE, CONCORD, N. H. In the ordinary court room are presented conditions that call for an ample volume of air and its thorough distribution. The frequent crowding of a criminal court room with the lowest class of society during a sensational trial, is certain to be accompanied by extraordinary pollution of the atmosphere. Vile odors and disease germs are rampant and their effect can only be overcome by the most bountiful supply of pure, fresh air.

A building devoted to the combined requirements of a court house and a State library is presented in Figs. 91 and 92. The court room, the wall of which is shown broken away in Fig. 91, extends up for the height of two stories. Two registers, in flues located in the inner wall, force the

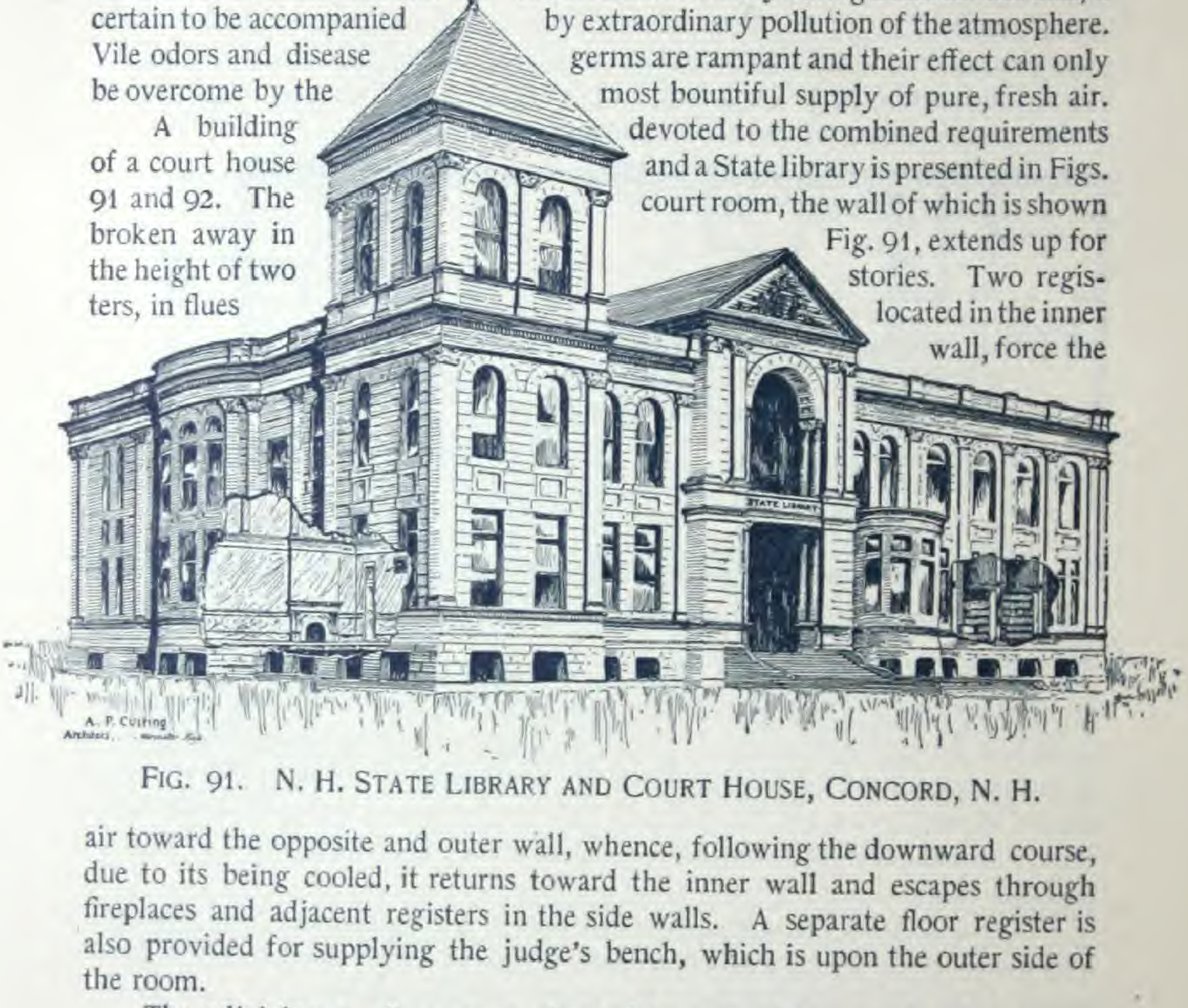


FIG. 91. N. H. STATE LIBRARY AND COURT HOUSE, CONCORD, N. H.

air toward the opposite and outer wall, whence, following the downward course, due to its being cooled, it returns toward the inner wall and escapes through fireplaces and adjacent registers in the side walls. A separate floor register is also provided for supplying the judge's bench, which is upon the outer side of the room.

The adjoining smaller rooms, devoted to uses of the court and jury, are treated as are similar apartments in other buildings, with supply from overhead registers in the inner walls and ventilating registers at floor level and in the same walls when possible.

The library portion of this building, as will be seen by Fig. 92, consists of a main stack room with alcoves. In each of the partition walls between alcoves

are located vertical flues from which hot air is delivered to each alcove, thereby keeping their most exposed portions warm. Thence it passes to the main room with its less exposure, whence it escapes through ventilating registers, as indicated. The great value of the books of a library necessarily demands the utmost care in the introduction of the heating system to the end that they may not be injured

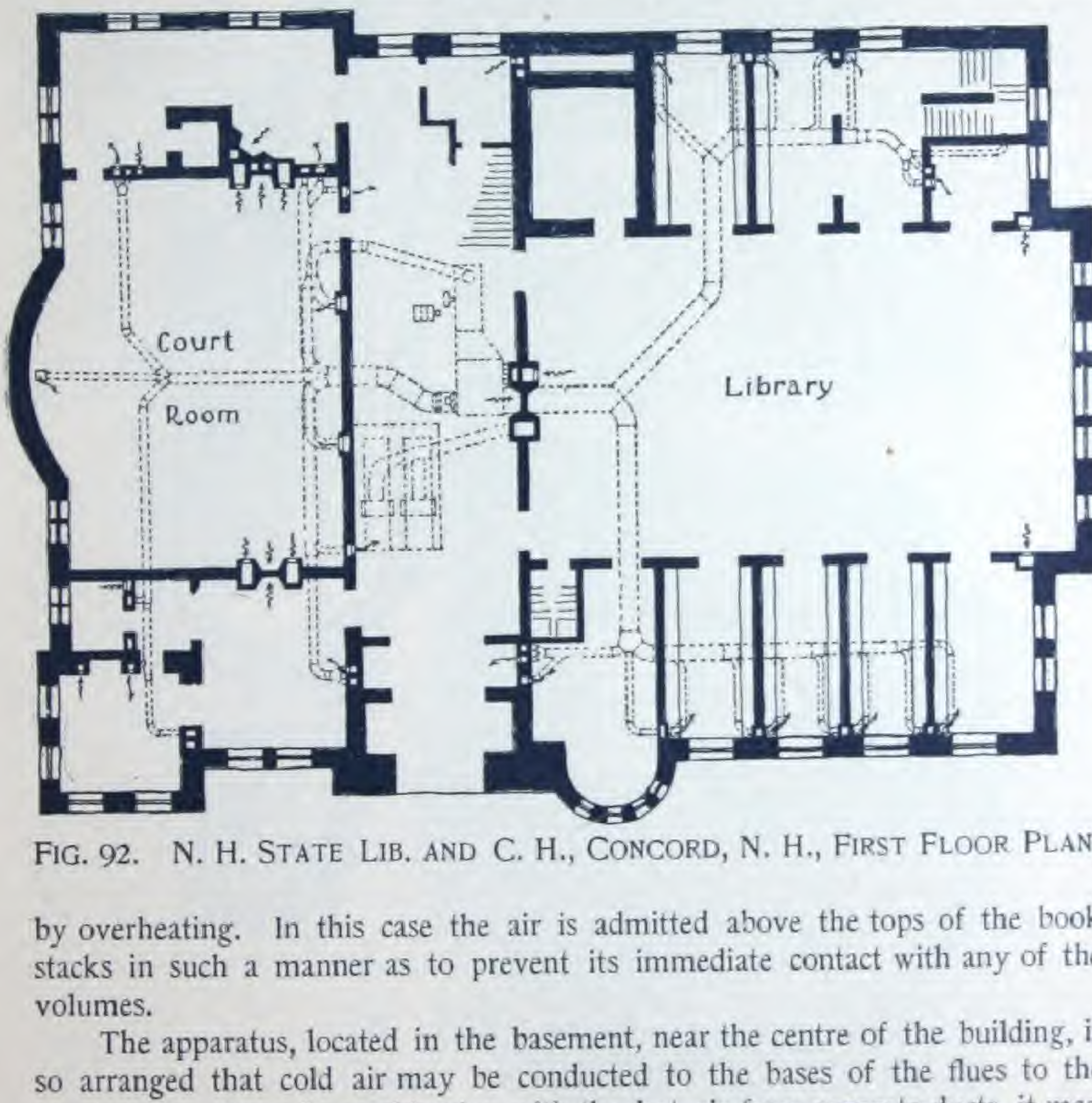



FIG. 92. N. H. STATE LIB. AND C. H., CONCORD, N. H., FIRST FLOOR PLAN.

by overheating. In this case the air is admitted above the tops of the book stacks in such a manner as to prevent its immediate contact with any of the volumes.

The apparatus, located in the basement, near the centre of the building, is so arranged that cold air may be conducted to the bases of the flues to the court room, where, in combination with the hot air from separate ducts, it may be admitted to the court room, but constantly under the regulating power of thermostats, which thereby maintain a constant temperature within the apartment without affecting the volume of air admitted.

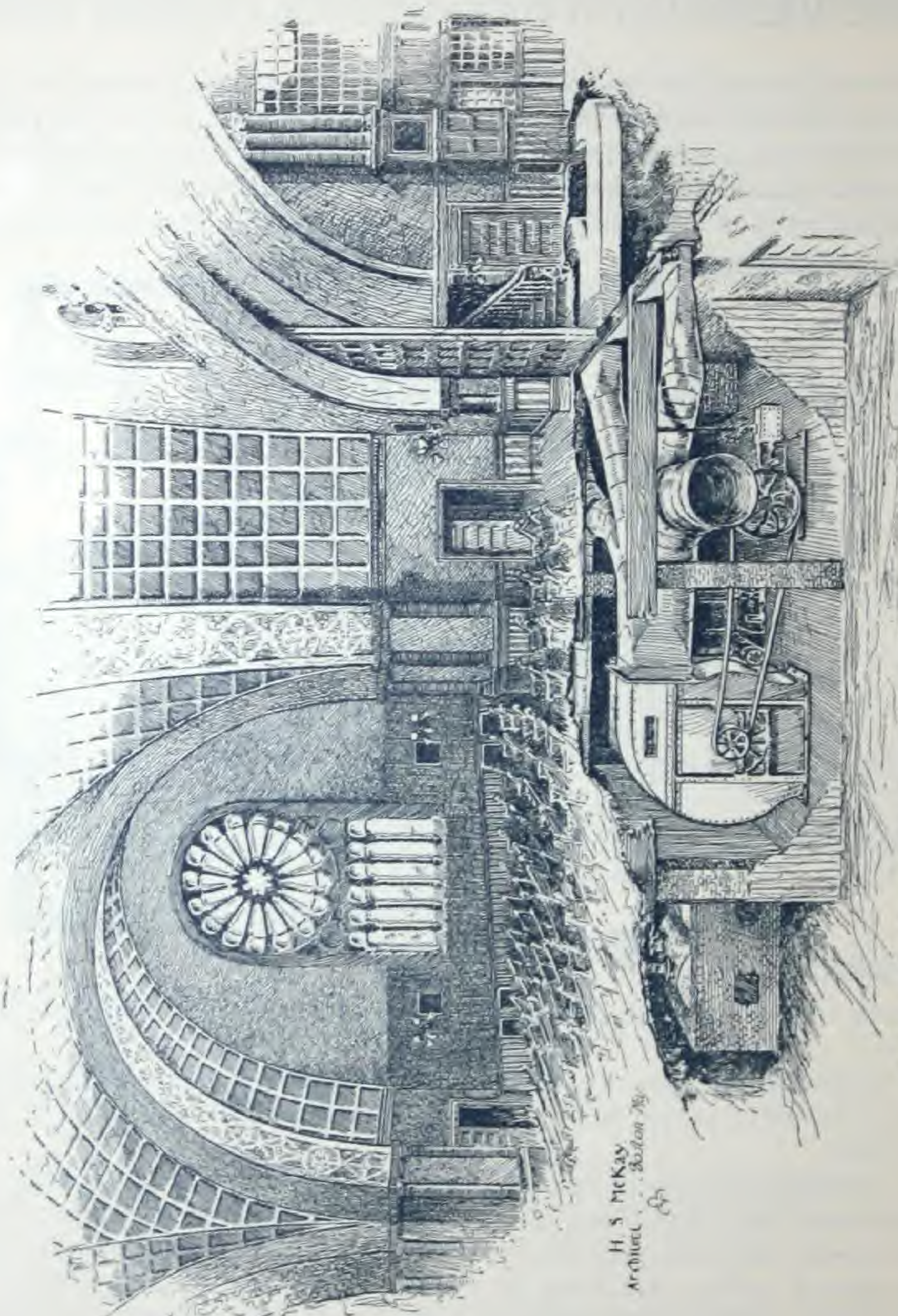



FIG. 93. FIRST BAPTIST CHURCH, MALDEN, MASS.

# VENTILATION AND HEATING

## CHURCHES.

The treatment of a church depends largely upon its design. If the floor is arranged upon the amphitheatre plan, the air may be admitted much as in the case of a theatre. But the usual construction presents a floor that is practically level and compels the introduction of air vertically through it, or else its supply from the side walls. To secure the best distribution the latter arrangement is usually adopted, rendering the manner of heating the ordinary church but little different from that of a hall of audience.

The intermittent use of a church, however, introduces one of the most important problems in the design and introduction of a heating and ventilating system. As a rule, upon Sunday, practically all the rooms in the building are in use, sometimes the auditorium and Sunday-school rooms coincidently, sometimes consecutively, while less frequently one is occupied in the morning and the other in the afternoon. Furthermore, the parlors, pastor's study, or small lecture rooms, may be required to be warmed only on certain days of the week.

Evidently, then, the system installed must be varied in its adaptability and rapid in its ability to warm up the building after it has been thoroughly cooled down. For the occasional warming of small rooms where ventilation is not an all-essential feature, direct radiation will be found most advantageous, while provision may also be made for supplying air to the same apartments when the apparatus is in operation.

FIRST BAPTIST CHURCH, MALDEN, MASS. In the structure illustrated in part in Fig. 93, the auditorium and Sunday-school are located upon the same floor, the latter being flanked upon two sides by two tiers of classrooms and parlors, arranged to be separated from, or form a part of, the main room at will. The apparatus is located in the basement, near the centre of the structure, and pipes extend therefrom to the various vertical flues, the location of a sufficient number of which is indicated to make the arrangement clear. Each flue in the side walls of the auditorium is provided with two registers, the lower at floor level, to be employed when first warming up. Ventilation takes place through wall registers set near the floor, whence the foul air passes to the roof space and out of a roof ventilator.

The main Sunday-school room is supplied and ventilated as indicated by the location of the registers, while the classrooms and parlors are individually heated and ventilated. Direct steam radiators additionally heat certain of the apartments. The social hall in the basement is supplied directly from the fan.

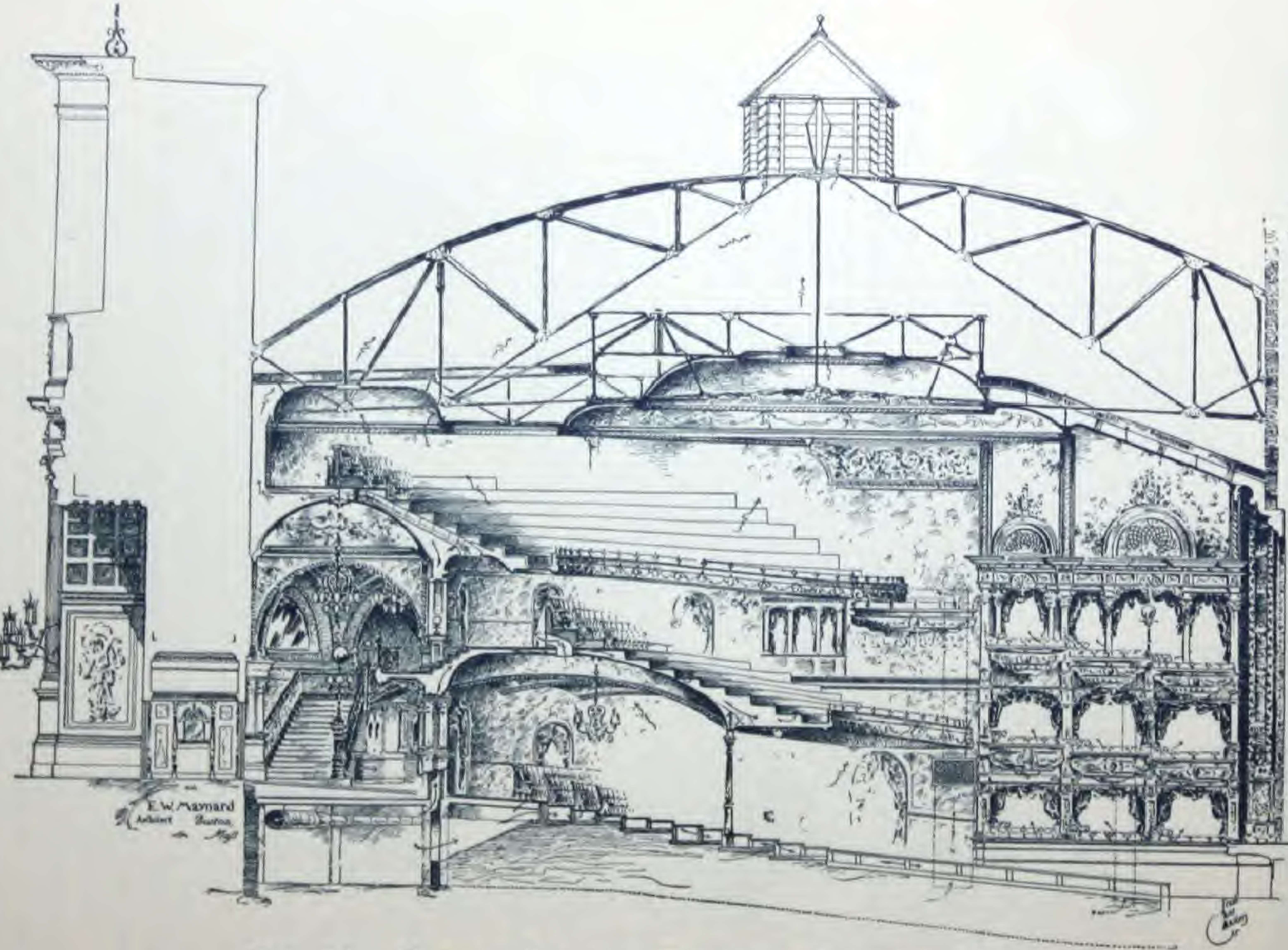



FIG. 94. CASTLE SQUARE THEATRE, BOSTON, MASS.

# VENTILATION AND HEATING

## THEATRES.

Theatres, of all halls of audience, require the greatest care and the most extended experience in the designing of a system of ventilation and heating adequate for their requirements. They consist of three different parts: the entire body of the house or auditorium; the stage and dressing rooms; and the foyer, lobbies, corridors, stairways and offices. But the distinction and separation between these different parts changes at different times during a performance. The simple rising of the curtain throws into one the two previously distinct apartments — the auditorium and the stage. So too, when all the doors or portieres are opened into the corridors, the distinction between the auditorium and corridors is materially lessened. It will be readily seen that arrangements based entirely upon the constant separation of these various apartments may be seriously affected, if it is possible to so suddenly and radically change these conditions.

As a rule, theatres are located in cities with buildings abutting on two or more sides and allowing of no direct connection, by windows, with the external air. In fact, none but artificial means can ever produce satisfactory results in such places, and, furthermore, only a system of forced circulation has complete control over all conditions. Generally speaking, it is advisable to create a slight excess of pressure in the auditorium, in order that all openings shall allow for the discharge, rather than for the ingress of air. This condition will cause the curtain to swell slightly toward the stage, and will ensure the leakage of air from the auditorium to the corridors rather than the reverse, which under certain conditions may be decidedly objectionable. The general methods of air introduction and distribution in such a building have already been pointed out.

The close seating of the occupants produces a large amount of animal heat, generally increasing the temperature five or six degrees and, quite frequently, fully ten degrees, evidently so much that, considering a theatre once filled and thoroughly warmed, it usually becomes not so much a question of warming as of cooling to produce comfort. Occupied as such buildings are for a number of hours, a continuous working system must be provided, and no reliance placed on one that puts the atmosphere in good condition at the beginning of a performance, but fails to maintain that good condition to the end. Architects have during late years devoted a great deal of attention to this matter, with marked improvement in the condition of newly-constructed theatres. Many failures have, however, resulted from inexperience, and a lack of realization of extraordinary requirements in such structures.

# VENTILATION AND HEATING

CASTLE SQUARE THEATRE, BOSTON, MASS. Evidently there is great opportunity for variety in the heating and ventilating arrangements that may be introduced in a theatre. While side wall flues and openings may to a

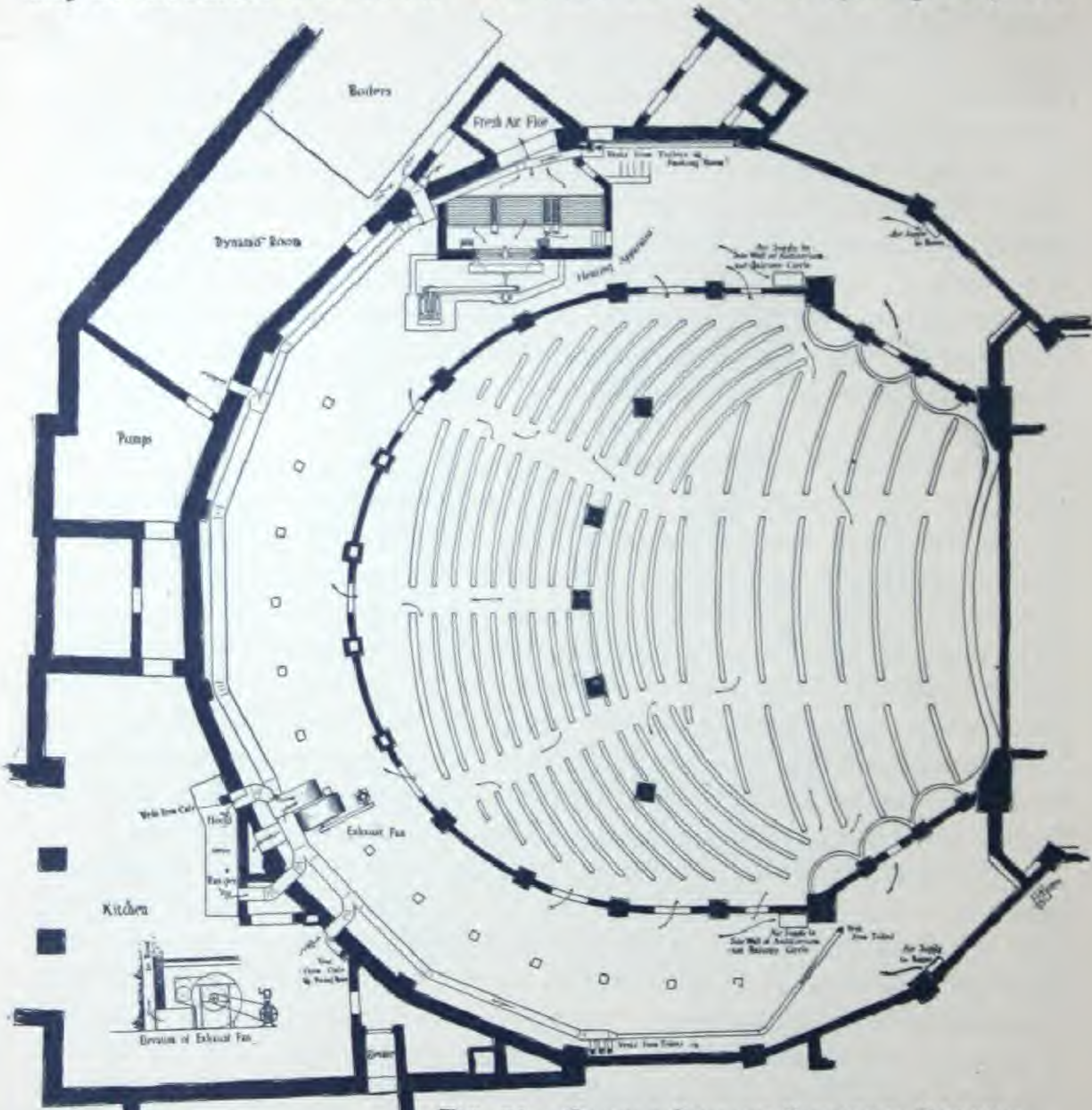



FIG. 95. CASTLE SQUARE THEATRE, BOSTON, MASS., BASEMENT PLAN.

certain extent fulfil the requirements, they are, nevertheless, so located that the air discharged therefrom can never do its most effective work in the way of ventilation. Although the system of ceiling supply by means of a plenum fan

discharging through a perforated ceiling, with a resulting downward movement of the air enforced by an exhaust fan drawing from floor openings, possesses many advantages, and has to a considerable extent been introduced, yet it has seemed advisable to illustrate here the more common method of floor supply and upward air movement.

In this theatre, clearly presented in its general arrangements in Figs. 94 and 95, there is practically no external exposure,—only a little more than the width of the doors upon either side. The front is faced with a hotel, as is also the rear of the stage. Therefore, the entire theatre is, to all practical purposes, entirely enclosed.

The skeleton structure is of steel beam and girder work, while all arches, partitions and similar portions are of tile or terra-cotta, making an ideally fire-proof structure. Immediately surrounding the orchestra circle is the usual partition separating it from the foyer and lobbies. Above the level of the first floor this partition is formed of a double wall of terra-cotta, with space between. The space in the basement between this partition and the outer wall of the theatre forms a passage or conduit some ten feet in height.

Located in this passage, at a point convenient to the fresh air supply from above the roof, is a special cone fan of the general type illustrated in Fig. 18, set to the extent of about half its diameter into a properly-shaped pit. Adjacent thereto is the heater enclosed in a brick chamber, while an engine furnishes the motive power to drive the fan by belt. The air (heated or otherwise, as may be necessary), as it leaves the fan, passes in properly-proportioned volumes in either direction along the passage, whence the greater part is allowed to escape to the space beneath the auditorium proper. In smaller volumes it is delivered to the first and second balconies through flues in the pilasters and through the hollow walls at the rear of the auditorium. Through the large flues, near the boxes, and upon either side of the auditorium, air passes to large wall registers, as shown in the section, and also to the space beneath the second balcony floor. The boxes are supplied through special flues, which discharge into the passages with which they connect, whence the air enters the boxes beneath the doors, which are cut short, and passes across the occupants to the body of the house.

The principal supply for the auditorium—amounting to nearly 30,000 cubic feet per minute for the orchestra and orchestra circle alone, and as much more for the balconies,—is admitted through the floors of these respective portions. In the case of the main floor, the space beneath it permits of the ready distribution of the air admitted thereto through the numerous openings in the basement partition wall.

The chair legs throughout the entire house are provided with special latticed castings, as shown in Fig. 96, forming thereby a large number of air chambers to which air is discharged through openings in the floor immediately beneath them. The air thus passing through the floor openings at relatively high velocity is permitted to escape beneath the persons of the occupants with low and imperceptible movement, and then pass upward to the ceiling vents.

These vents, consisting of a central ceiling opening of moderate size and numerous smaller openings in the ceiling at the back of the second balcony, provide for a backward sweeping movement of the air across both first and second balconies, thereby securing the highest efficiency from a given volume of air. Special ventilation from the orchestra circle and the extreme rear of the first balcony is also indicated in the sectional view. The large ventilator at the highest point of the roof, which allows of escape of all foul air from the roof space, is provided with a special closing damper to be operated from the basement.

FIG. 96.

All escape of odors from the toilet and smoking rooms to other apartments is avoided by providing special and positive exhaust ventilation therefrom by means of an exhaust fan, located in the basement, which connects with a series of vertical flues. The same fan also serves to remove the heated air and odors from the kitchen and the boiler and dynamo rooms beneath the hotel.

The foyer is supplied with warm air through registers in the walls beneath the stairs, and is independently ventilated through its triple-domed ceiling. The stage is heated by means of steam coils at the back suspended just beneath the floor, cast-iron gratings being provided through which the heated air may pass upward.

The temperature throughout the auditorium is regulated by a thermostat arranged to operate a by-pass damper on the heater, so that any desired temperature of the air passing to the conduit may be secured. To avoid trouble from too great and sudden cooling of the air, a minimum thermostat is also introduced, which, as usually set, prevents the admission of air to the auditorium at a temperature lower than 65°. With this arrangement this temperature is readily and uniformly maintained at 70° throughout the house, while 30 cubic feet and over is supplied per minute to each occupant.

# VENTILATION AND HEATING

## DWELLINGS AND OTHER BUILDINGS.

While characteristic types have been chosen for illustration in the preceding pages, it must be evident that it is impossible in this comparatively small compass to completely cover the wide range of variety in the construction and uses of buildings. The dwelling house, for instance, has not been presented, but it by no means follows that its ventilation and heating may not be easily accomplished. Simply because of the similarity of treatment of an office building and a dwelling the latter has not been illustrated.

While the Sturtevant System meets the requirements of domestic heating and ventilation, nevertheless, because of its mechanical nature it is more or less unsuitable for introduction in a moderate-sized dwelling. But in the large private residence or in the apartment house, where careful attendance is assured, it evidently surpasses any other method. Objectionable furnace gas is avoided, danger from leaking direct-steam or hot-water radiators cannot occur, and the supply of air is no longer at the mercy of the atmospheric changes.

In its most perfect form the hot and cold arrangement of the system should, of course, be installed; but the single-pipe system will, under ordinary conditions, meet the requirements of good ventilation, for the air supply by the Sturtevant System is usually far in excess of the requirements. The perfection of the electric motor and the extension of power circuits is simplifying the introduction of the system in dwellings, for under such conditions of power supply low-pressure steam may be employed for the heating and the speed of the motor, and consequently the movement of the fan readily regulated.

For either the permanent or temporary heating of large, open structures like exhibition buildings this system is particularly adapted. It secures uniformity in the warming, and by means of an apparatus that is readily portable. The Horticultural Building, at the World's Columbian Exhibition, was thus treated, apparatus of large capacity being placed within the huge floral mound which stood just beneath the dome. From the highest point of this mound the warm air was discharged, volcano-like, toward the glass-roofed dome, whence by its cooling action it gradually setttled to the floor and was thence drawn back once more to the apparatus. Evidently, after the Fair, the various apparatus, unlike a lot of direct-steam piping, were still in marketable form.

The Sturtevant System has been extensively employed for the double purposes of heating dye houses, paper mills, and the like, where great quantities of steam are produced, and of clearing the interior atmosphere by absorbing this steam by means of the large volumes of heated air.

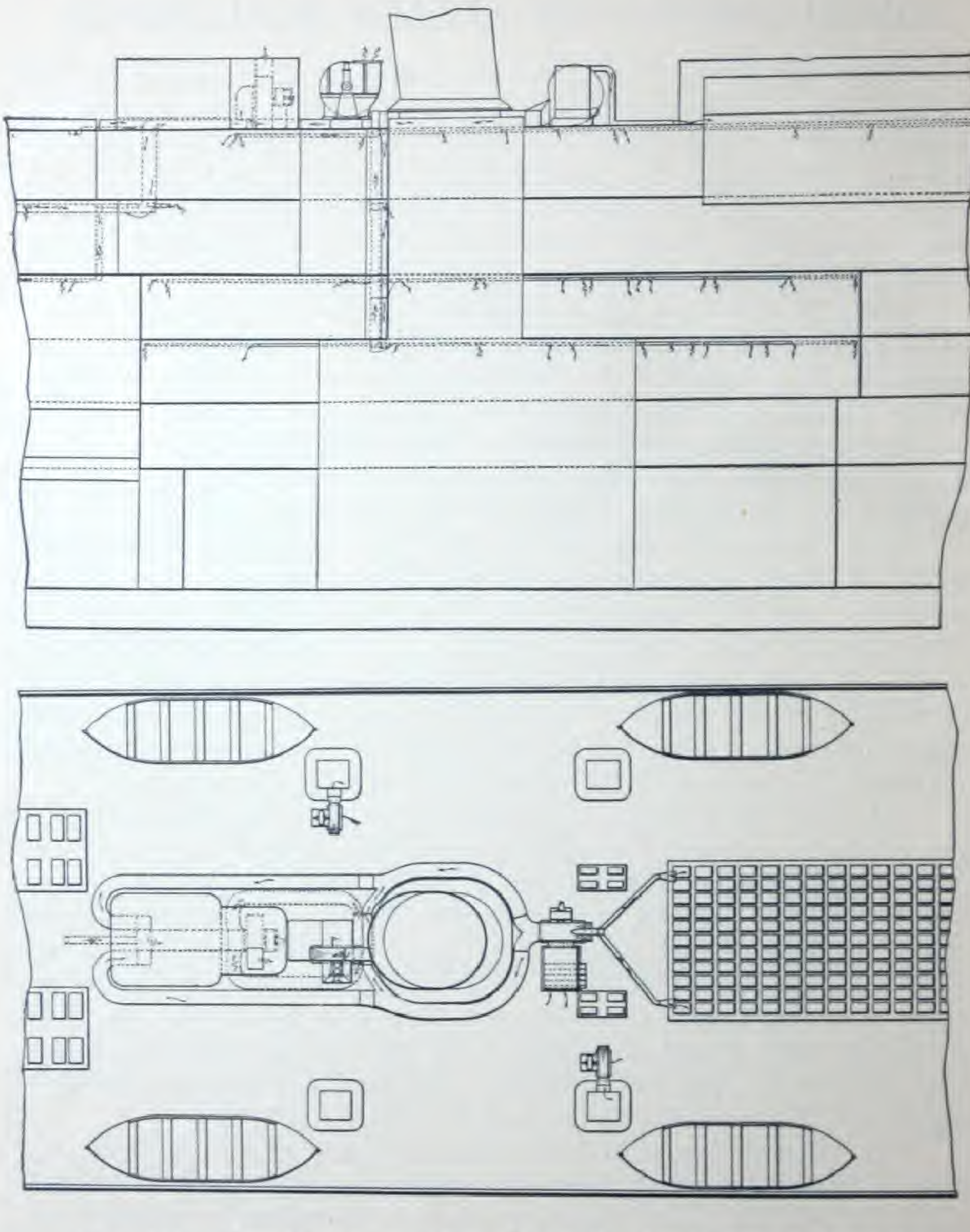


FIG. 97. STEAMSHIPS "ST. PAUL" AND "ST. LOUIS."

# VENTILATION AND HEATING

## STEAMSHIPS.

While efforts are continually being made by all the great steamship companies, notably those that compete for the travel between Europe and America, to improve their ships, reduce their time of passage, and to make comfortable the passengers, no expense being spared in decorations and luxurious fittings of the saloons and rooms which are the temporary home of travellers, it is a pleasure to be able to record the fact that the matter of ventilation is now receiving its share of attention. There is no doubt that one of the greatest defects in a modern steamship has been the failure to provide an adequate and constant supply of pure air at all times and in all parts of the ship that are occupied by passengers and crew. Much of the discomfort of an ocean voyage, including seasickness, arises from the bad air which every one is obliged to breathe when below decks with the air ports closed, especially in rough weather. The remedy is simple, effectual and inexpensive. By means of a fan the staterooms and saloons can be given the freshness of the outer air, instead of the stuffy and oppressive atmosphere that now characterizes them.

The problem is of equal importance in naval vessels, and the course of its inception and successful solution in the American Navy has had a great influence in leading the merchant marine to adopt this most beneficent improvement.

In March, 1878, the Secretary of the Navy appointed a board of officers "to examine and ascertain the best system of ventilation, by mechanical means or otherwise, by which the ships of the Navy may be more perfectly ventilated than at the present time." This board made an examination of the U. S. S. "Richmond," and reported: First, upon the necessity of ventilation, showing "the filthy condition of the atmosphere generally on shipboard, which both men and officers are compelled to breathe; thus inducing disease, impairing health and increasing the mortality." Second, upon the necessity of some mechanical device to keep up the circulation of air, giving reasons why "no system of ventilation can be relied upon which depends for action on induced currents produced by the difference of densities or the difference in the static and dynamic heads of the internal and external air." As a mechanical device for ventilating, it was recommended "that a fan of the most improved type, and one that has been thoroughly tested and found efficient, be adopted."

Two fans, the first constructed for this purpose, were built by B. F. Sturtevant. After twenty-five days at sea, Chief Engineer Baker wrote: "It may be confidently stated, that the 'Richmond' is now by far the most completely ventilated ship that ever sailed under the American flag, or, indeed, under any flag."

# VENTILATION AND HEATING

STEAMSHIPS "ST. PAUL" AND "ST. LOUIS." These magnificent new twin transatlantic liners of the International Navigation Co. undoubtedly stand to-day as the most perfectly heated and ventilated vessels afloat. All other means of heating were discarded, and the Sturtevant System adopted throughout. The system is duplex in its operation, one series of fans, with their attached heaters, serving to furnish pure warm air to practically all occupied portions of the ships, while a separate set of exhausting fans is arranged to withdraw the air, and to thereby compel its complete circulation.

The presence of water-tight bulkheads naturally prevented the horizontal extension of air pipes throughout the lower decks. Four separate plants were therefore introduced, each plant consisting of a heating and an exhausting apparatus, both located on the shade deck, and driven by direct-connected electric motors. From each of these apparatus pipes extend downward, and upon each deck connect with horizontal systems; no pipes passing through the transverse bulkheads. The general scheme of this arrangement is indicated in Fig. 97, showing, in outline, a longitudinal section and plan of the shade deck which embraces one of these systems. Smaller auxiliary fans, one shown on either side of the ship, supply fresh, cool air direct to the engine rooms, while the large fan, presented in side elevation, is devoted solely to exhausting from the galley.

FIG. 98.
STATEROOM.

All pipes are carried close up to the deck or deck beams above. On the berth deck the supply ducts are extended down each of the stateroom alcoves, discharging the air overhead toward the side of the ship, as indicated in Fig. 98. Positive circulation throughout the stateroom is accomplished by extending an exhaust pipe down behind the commode and dressing case, as shown, and providing it at the bottom with a suitable opening. The latticed panel permits of ready passage of air when the door is closed.

# TESTING SYSTEMS OF VENTILATION AND HEATING.

The actual efficiency of any system of ventilation and heating cannot be ascertained by mere casual inspection, but only by careful, intelligent and extensive experiment. Trustworthy results can only be obtained by the use of special instruments designed for such investigations. Among the most important for this purpose are those here presented.

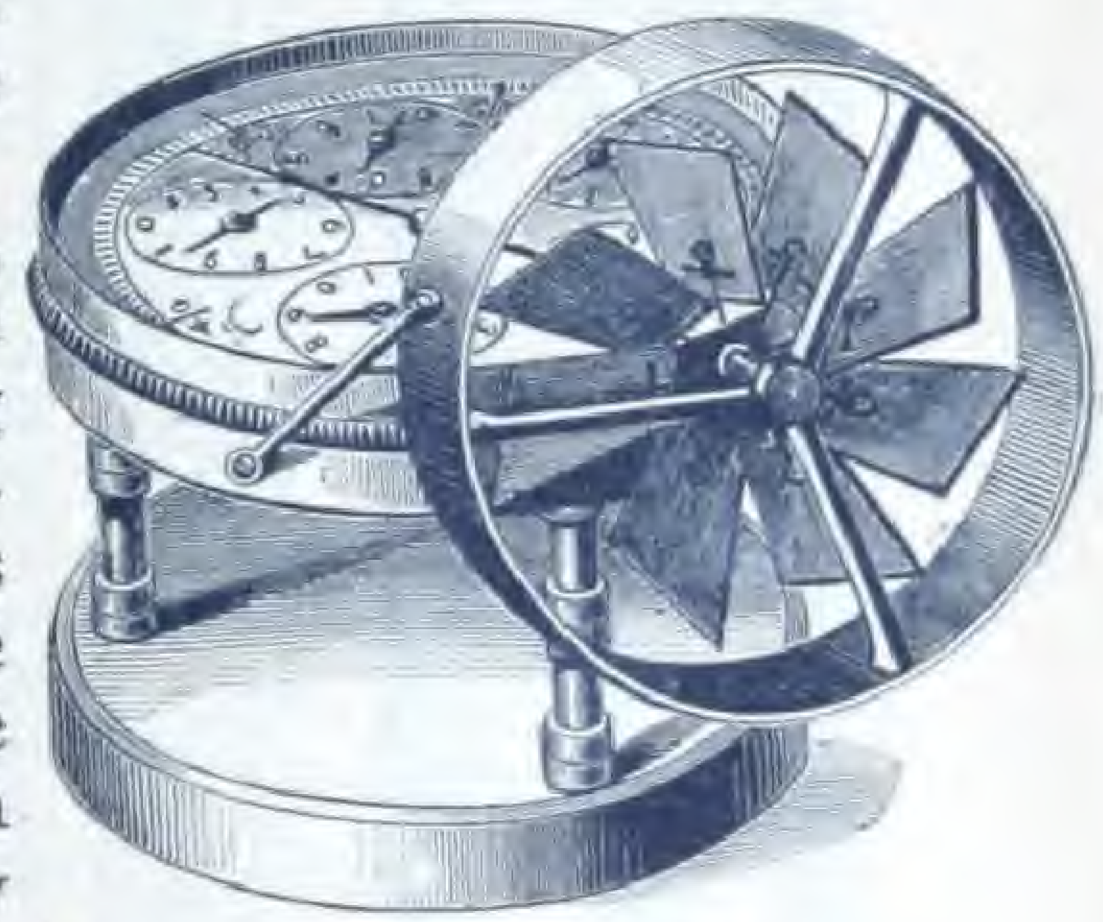


FIG. 100. ANEMOMETER.

Good thermometers, of the usual construction, are generally sufficiently accurate for observing the ordinary temperature of air, but for noting the temperature of steam, or of highly-heated air, the form shown in Fig. 99 is very convenient. The thermometer tube is enclosed in a tubular brass case, the lower end of which is provided with a screw of standard size and thread, by means of which it may be securely inserted in any T or flange. The tube projects well down below the threaded portion, and is guarded by a small pipe attached to the bottom of the case, which allows free circulation around the bulb of the thermometer. The glass may be graduated to read between any given temperatures. For instance, if the thermometer is to be employed exclusively for ascertaining the ordinary temperature of steam, its range need not be greater than between the points 200° to 350°.

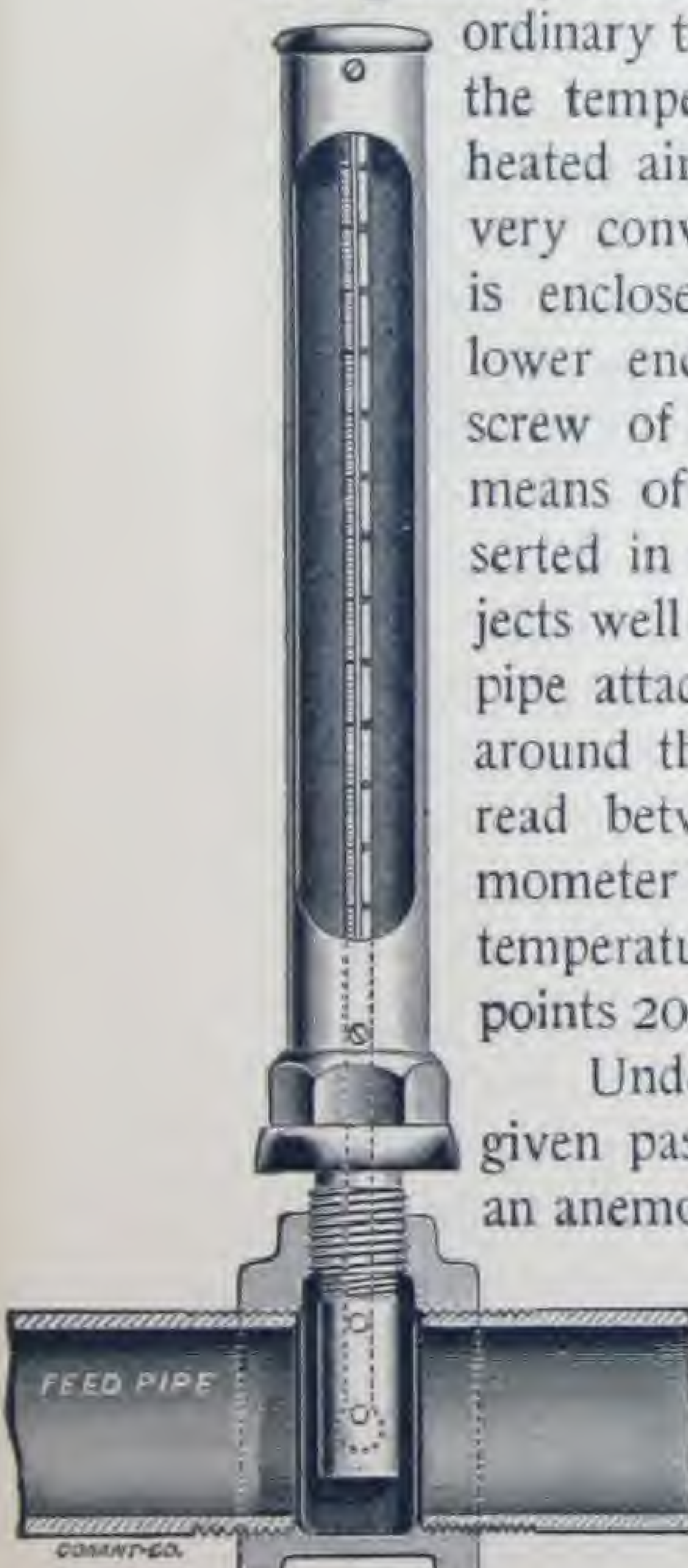



FIG. 99. HIGH-GRADE THERMOMETER.

Under ordinary conditions the volume of air flowing through a given passage or orifice may be most readily determined by means of an anemometer. This instrument, of the form illustrated in Fig. 100, consists of a light and delicately constructed fan wheel whose motion is transmitted to a practically frictionless system of gearing within the attached case. The movement of this system of gearing is rendered evident by the hands and graduated circles upon the dial. The velocity of the air, in feet per minute, is indicated thereon, the series indicating 100, 1,000, 10,000, 100,000, 1,000,000 and 10,000,000

respectively. Evidently the velocity thus obtained, corrected for any known error of the instrument, multiplied by the area of the passage, must give the total volume of air passing.

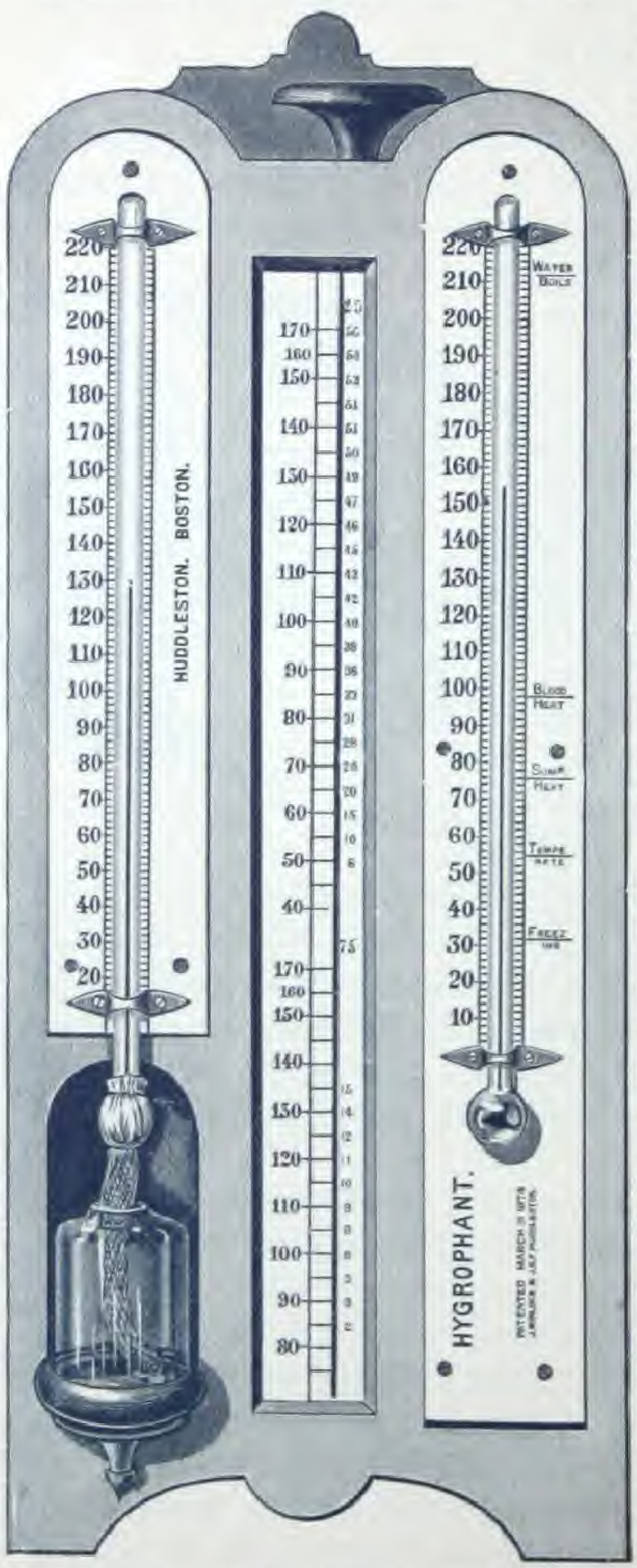



FIG. 101. HYGROMETER.

Air pressures may be determined by means of the ordinary U tube, one end being connected with the given space or passage and the other with the atmosphere, the difference in pressure being indicated by the difference in level of the water in the two legs of the tube. This reading of pressure differences in inches of water may be readily transformed into pressure in ounces by multiplying by .578 — this factor being the equivalent, in ounces, of the pressure due to a head of one inch of water.

The humidity of the air may be ascertained by a hygrometer, shown in its most convenient form in Fig. 101. It is provided with two standard thermometers, one — the dry bulb — showing the temperature of the air, the other — the wet bulb — the temperature due to evaporation. When the air is saturated no evaporation takes place, and the two thermometers indicate the same. Between the thermometers, and enclosed in the case behind the slot, is a cylinder arranged to be freely turned by the knob at the top, and upon which is inscribed a series of columns of figures numbered at their headings.

The instrument here shown was specially designed for high temperatures, and a double set of columns is given. These numbers represent the difference in temperature shown by the two ther-

mometers. The vertical columns beneath them exhibit the relative humidity, which may be read off beneath the figures at top of column, indicating the difference of temperatures and opposite to the temperature of the wet bulb, as shown on the scale at the left of the cylinder.

The amount of carbonic acid present in the atmosphere may be readily ascertained to a sufficiently close degree for practical purposes in the following manner. Six clean, dry and well-stoppered bottles, containing respectively 100, 200, 250, 300, 350 and 400 cubic centimeters, a glass tube containing exactly 15 cubic centimeters to a given mark, and a bottle of perfectly clear, fresh lime-water, constitute the apparatus required. The bottles should be filled by means of a hand-ball syringe with the atmosphere to be examined. Add to the smallest bottle 15 cubic centimeters of the lime-water, put in the cork and shake well. If turbidity appears, the amount of carbonic acid will be at least 16 parts in 10,000. If no turbidity appears, treat the bottle of 200 cubic centimeters in the same manner; turbidity in this would indicate 12 parts in 10,000. In similar manner, turbidity in the 250 cubic centimeter bottle indicates at least 10 parts in 10,000; in the 300, 8 parts; in the 350, 7 parts; and in the 400, less than 6 parts. The ability to conduct more accurate analyses can only be attained by special study and a knowledge of chemical properties and methods of investigation.